Proceedings of the I·R·E

A Journal of the Theory, Practice, and Applications of Electronics and Electrical Communication

Radio Communication • Sound Broadcasting • Television
Marine and Aerial Guidance • Engineering Education
Power and Manufacturing Applications of Radio-and-Electronic Technique
Industrial Electronic Control and Processes • Tubes • Electron Optics
Medical Electrical Research and Applications • Radio-Frequency Measurements
Sound and Picture Electrical Recording and Reproduction

BUY AT LEAST ONE EXTRA WAR BOND

SIXTH WAR LOAN

Bell Telephone Laboratories

WEDDING RADIO AND CONDUCTIVE TECHNIQUE
Ultra-High-Frequency Transmission Line

DECEMBER, 1944

VOLUME 32 NUMBER 12

The Institute of Radio Engineers

Proceedings of the I·R·E

Published Monthly by

The Institute of Radio Engineers, Inc.

VOLUME 32 — *December, 1944* — NUMBER 12

Responsibility for the contents of papers published in the PROCEEDINGS rests upon the authors. Statements made in papers are not binding on the Institute or its members.

Entered as second-class matter October 26, 1927, at the post office at Menasha, Wisconsin, under the Act of February 28, 1925, embodied in Paragraph 4, Section 538 of the Postal Laws and Regulations. Publication office, 450 Ahnaip Street, Menasha, Wisconsin. Executive, editorial, and advertising offices, 330 West 42nd Street, New York 18, N. Y. Price, $1.00 a copy. Subscriptions: United States and Canada, $10.00 a year; foreign countries, $11.00 a year. Changes of address (with advance notice of fifteen days) and communications regarding subscriptions and payments should be mailed to the Secretary of the Institute, at 330 West 42nd Street, New York 18, N. Y.

THE INSTITUTE OF RADIO ENGINEERS

INCORPORATED

1945 WINTER TECHNICAL MEETING
NEW YORK, N.Y.—JANUARY 24, 25, 26, AND 27, 1945

SECTION MEETINGS

ATLANTA December 15	**CHICAGO** December 15	**CLEVELAND** December 28	**DETROIT** December 15	**LOS ANGELES** December 19
NEW YORK January 3	**PHILADELPHIA** January 4	**PITTSBURGH** January 8	**PORTLAND** January 8	**WASHINGTON** January 8

SECTIONS

ATLANTA—Chairman, Walter Van Nostrand; Secretary, Ivan Miles, 554—14 St., N. W., Atlanta, Ga.

BALTIMORE—Chairman, W. I. Webb; Secretary, H. L. Spencer, Box 6760, Towson 4, Md.

BOSTON—Chairman, C. C. Harris; Secretary, Corwin Crosby, 16 Chauncy St., Cambridge, Mass.

BUENOS AIRES—Chairman, L. C. Simpson; Secretary, I. C. Grant, Venezuela 613, Buenos Aires, Argentina.

BUFFALO-NIAGARA—Chairman, A. J. Dybowski; Secretary, H. G. Korts, 51 Kinsey Ave., Kenmore, N. Y.

CHICAGO—Chairman, W. O. Swinyard; Secretary, A. W. Graf, 135 S. LaSalle, St., Chicago 3, Ill.

CINCINNATI—Chairman, J. L. Hollis; Secretary, R. S. Butts, Box 1403, Cincinnati 2, Ohio.

CLEVELAND—Chairman, A. S. Nace; Secretary, L. L. Stoffel, 1095 Kenneth Dr., Lakewood, Ohio

CONNECTICUT VALLEY—Chairman, R. F. Shea; Secretary, L. A. Reilly, 989 Roosevelt Ave., Springfield, Mass.

DALLAS-FORT WORTH—Chairman, D. J. Tucker; Secretary, P. C. Barnes, WFAA-WBAP, Grapevine, Texas.

DAYTON— Chairman, George L. Haller; Secretary, Joseph General, 1319 Superior Ave., Dayton 7, Ohio.

DETROIT—Chairman, R. A. Powers; Secretary, R. R. Barnes, 1411 Harvard Ave., Berkley, Mich.

EMPORIUM—Chairman, H. D. Johnson; Secretary, Albert Dolnick, Sylvania Electric Products, Inc., Emporium, Pa.

INDIANAPOLIS—Chairman, H. I. Metz; Secretary, J. D. Colvin, 328 E. 47 St., Indianapolis, Ind.

KANSAS CITY—Chairman, A. P. Stuhrman; Secretary, R. N. White, 4800 Jefferson St., Kansas City, Mo.

LONDON—Secretary, R. Wilton, Royal Canadian Air Force, Clinton, Ont., Canada

LOS ANGELES—Chairman, L. W. Howard; Secretary, Frederick Ireland, 1000 N. Seward St., Hollywood 38, Calif.

MONTREAL—Chairman, F. S. Howes; Secretary, J. A. Campbell, Northern Electric Co., Ltd., 1261 Shearer St., Montreal, Que., Canada.

NEW YORK—Chairman, Lloyd Espenschied; Secretary, J. E. Shepherd, 111 Courtenay Rd., Hempstead, L. I., N. Y.

OTTAWA—Acting Secretary, L. F. Millett, 33 Regent St., Ottawa, Ont., Canada

PHILADELPHIA—Chairman, T. A. Smith; Secretary, Samuel Gubin, RCA Victor Division, Radio Corporation of America Bldg. 8-10, Camden, N. J.

PITTSBURGH—Chairman, T. C. Kenny; Secretary, R. K. Crooks, Box 2038, Pittsburgh 30, Pa.

PORTLAND—Chairman, W. A. Cutting; Secretary, W. E. Richardson, 5960 S.W. Brugger, Portland, Ore.

ROCHESTER—Chairman, G. R. Town; Secretary, Harold Goldberg, Stromberg-Carlson Co., Rochester 3, N. Y.

ST. LOUIS—Chairman, N. B. Fowler; Secretary, C. H. Meyer, KFUO, 801 DeMun Ave., St. Louis, Mo.

SAN FRANCISCO—Chairman, W. G. Wagener; Secretary, R. V. Howard, Associated Broadcasters, Inc., Mark Hopkins Hotel, San Francisco 6, Calif.

SEATTLE—Chairman, F. B. Mossman; Secretary, E. H. Smith, Apt. K, 1620—14 Ave., Seattle 22, Wash.

TORONTO—Chairman, E. O. Swan; Secretary, Alexander Bow, Copper Wire Products, Ltd., 137 Roncesvalles Ave., Toronto, Ont., Canada.

TWIN CITIES—Chairman, H. S. McCartney; Secretary, C. W. Engelman, 4648 Chowen Ave. S., Minneapolis 10, Minn.

WASHINGTON—Chairman, J. D. Wallace; Secretary, F. W. Albertson, c/o Dow and Lohnes, Munsey Bldg., Washington 4, D. C.

WILLIAMSPORT—Chairman, H. E. Smithgall, Jr.; Secretary, K. E. Carl, Williamsport Technical Institute, Williamsport, Pa.

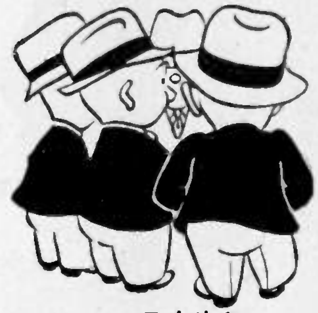
I R E Winter Technical Meeting

Hotel Commodore
New York City

January 24, 25, 26 & 27, 1945

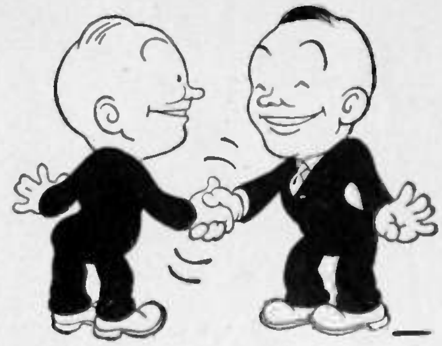
Annual Meeting:

This is the war-time equivalent of the I.R.E. National Convention and the major annual meeting of the Institute.



Technical Papers

An exceptionally interesting group of technical papers have been arranged. The trend of the War and approaching peace make valuable the papers planned for this timely meeting.



President's Luncheon

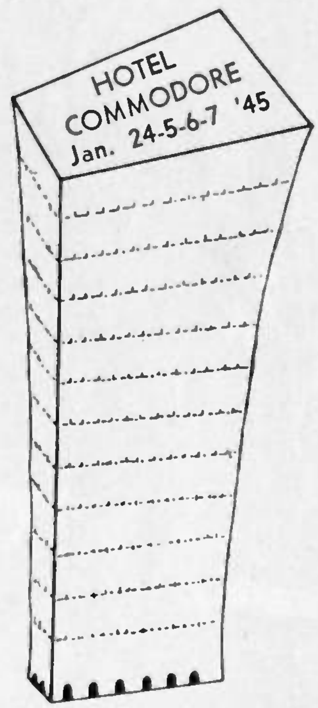
This is just-one of many opportunities for friendly greetings our Meeting provides.

Exhibits

The Radio Engineers' Show has been resumed as a part of the I.R.E. Annual Meeting. 31 Manufacturers will show equipment and component parts on a scale in keeping with War-time conditions.

Women's Program

For the first time since 1942, enjoyable activities for women have been arranged and it is hoped many will attend.



Service Men's Program

The Saturday Morning Session will be devoted to papers of special interest to engineers in the Armed Forces.

Banquet

The Annual I.R.E. Banquet will be held Thursday Evening, January 25th in the Grand Ballroom. (Informal)

He reserved his room

Cocktail Party—Sections Meeting

Park benches are cold beds!

Use this Coupon NOW!

The hotel situation in New York is acute and there is a definite limit to accommodations. Please tear off coupon and send in your requirements promptly to insure reservations.

Institute of Radio Engineers
330 West 42nd St., New York 18

The Institute of Radio Engineers
Winter Technical Meeting—Hotel Commodore, New York City

I R E

1945

GENTLEMEN:
PLEASE MAKE RESERVATIONS FOR PERSON(S) NAMED FOR ARRIVAL ON:

DATE .... AT .... A.M. P.M. DEPARTING ....

SELF (AND WIFE) .... TYPE .... ROOM, RATE $ ....

.... TYPE .... ROOM, RATE $ ....

NAME ....

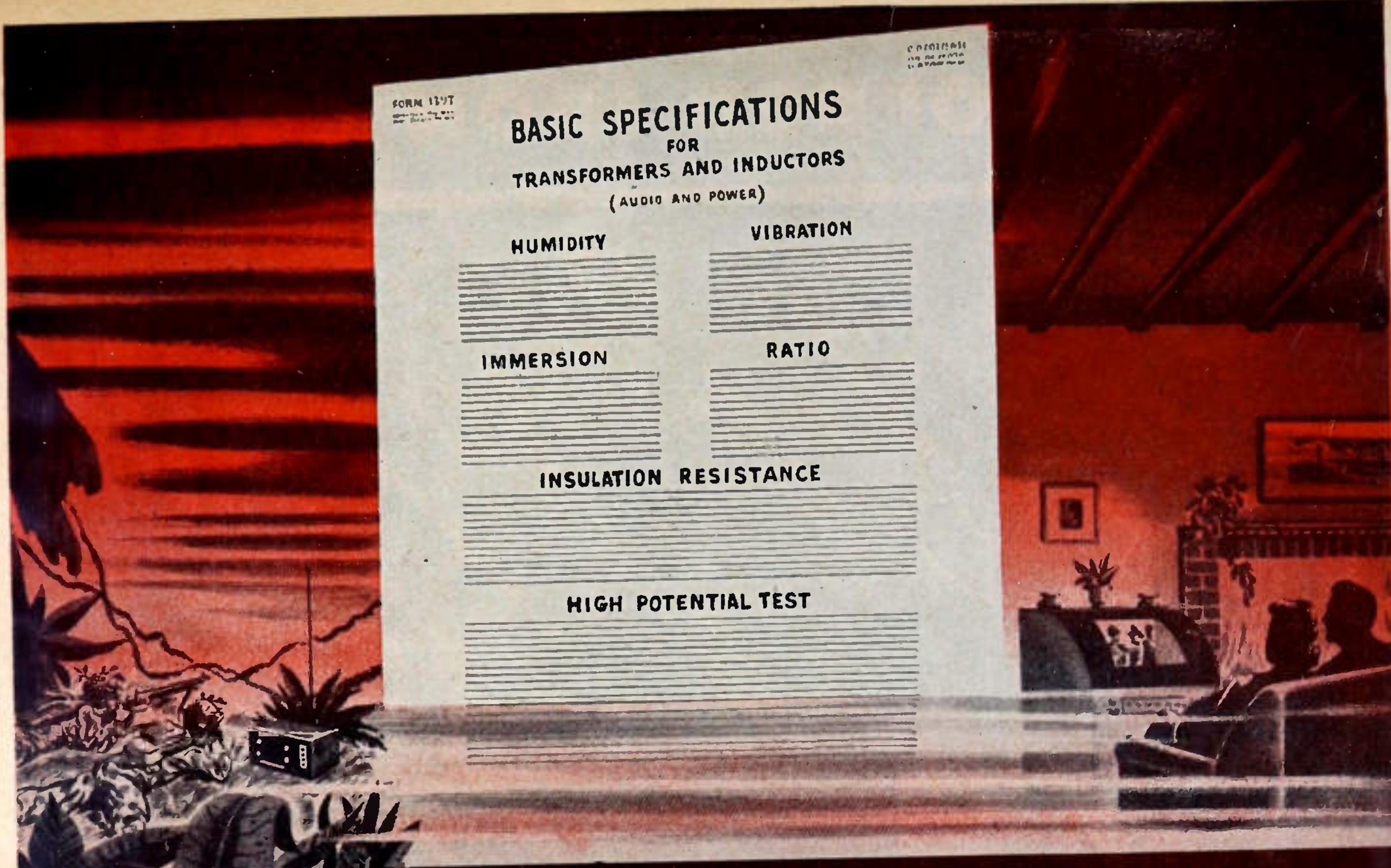
ADDRESS ....

ORGANIZATION ....

The following are Hotel Commodore Rates

TYPE A ROOM	TYPE B ROOM	TYPE C ROOM	TYPE D SUITE
SINGLE \$3.50—\$3.85—\$4.40 \$4.95—\$5.50	2 Persons—Double Bed \$5.50—\$6.05—\$6.60 \$7.15	2 Persons—Twin Beds \$6.60—\$7.15—\$7.70 \$8.80	2 Persons \$12.00 to \$16.00

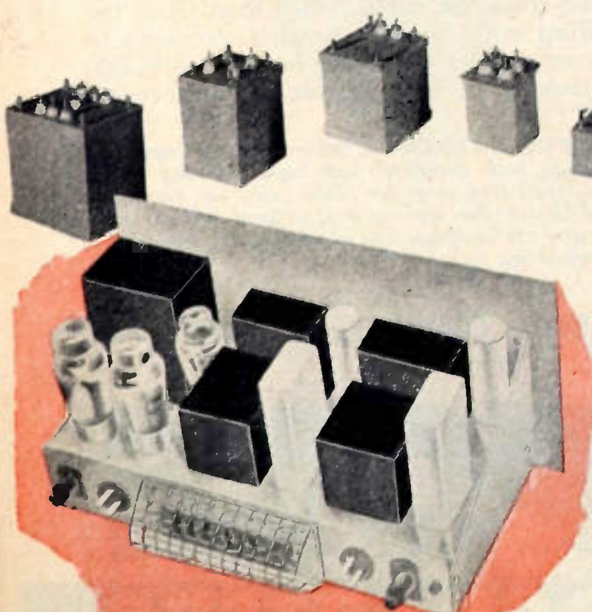
ALL ROOMS HAVE PRIVATE BATH AND CIRCULATING ICE WATER
Clip and mail to Convention Dept., Hotel Commodore, New York City



CONFORMANCE TO SPECIFICATIONS—TO THE LETTER

And the Spirit

At AmerTran, conformance to every detail—and implication—of the most rigid Army or Navy specifications is taken literally. Routine precautions include: vacuum impregnation and slow-baking of coils, infra-red heating to insure complete filling with insulating compound; torque gauging and resilient gaskets to protect ceramic terminals; induction heating for soldering operations to insure perfect hermetic sealing. Quality control is maintained by frequent inspections during the manufacturing process.



After the war, similar extraordinary care will be needed. Video-f.m.-a.m. and other combinations will complicate sets and circuits—emphasizing the need for perfectly coordinated components. That means rigid adherence to the letter AND THE SPIRIT of specifications—what AmerTran has been furnishing for forty-three years. Write or phone us, today.

AMERICAN TRANSFORMER CO., 178 Emmet St., Newark 5, N.J.

AMERTRAN

Pioneer Manufacturers of Transformers, Reactors and Rectifiers for Electronics and Power Transmission

Proving ground for Norelco Cathode Ray Tubes

THE uniform characteristics, long life and outstanding performance of NORELCO Cathode Ray Tubes are the result of exceptional manufacturing skill supplemented by rigid tests applied to each tube as it comes off the production line.

As an example of the care exercised, the electronic test set, shown here, subjects every cathode ray tube to 30 different checks, such as line width, light output, plate alignment, base-to-shell alignment, uniformity of cathode surface, astigmatism, presence of gas, and screen condition. A total of 90 exacting tests of raw materials, parts, sub-assemblies, assemblies and performance guard cathode ray tube quality.

This is typical of the great lengths to which North American Philips goes in producing high performance NORELCO electronic tubes. Behind this company is an organization with world-wide experience resulting from over fifty years of electrical research and development.

Although all the tubes we produce now go to the armed forces, we invite inquiries from prospective users. A list of tube types we are especially equipped to produce will be sent on request.

Uniformly bright spot on screen of 5CP1 cathode ray tube in test set indicates perfectly formed cathode.

Pattern used for measuring light output by means of photoelectric cell. Frequency—60 x 2940 cycles.

Trace showing absence of astigmatism. Frequency—60 x 420 cycles.

Write today for interesting booklet, describing the background of North American Philips in the science of electronics.

NORELCO PRODUCTS: Quartz Oscillator Plates; Amplifier, Transmitting, Rectifier and Cathode Ray Tubes; Searchray (X-ray) Apparatus; X-ray Diffraction Apparatus; Medical X-ray Equipment, Tubes and Accessories; Electronic Measuring Instruments; High Frequency Heating Equipment; Communications Equipment; Tungsten and Molybdenum products; Fine Wire; Diamond Dies. When in New York, be sure to visit our Industrial Electronics Showroom.

Norelco Reg. U. S. Pat. Off. *Electronic Products by* **NORTH AMERICAN PHILIPS COMPANY, INC.**

Dept. F-12, 100 East 42nd Street, New York 17, N. Y.
Factories in Dobbs Ferry, N. Y.; Mount Vernon, N. Y. (Metalix Div.); Lewiston, Me. (Elmot Div.)

COLONEL JOHN CASEY, *Manager, Chicago Municipal Airport . . .*

Colonel Casey said, "The growing complexities of airport traffic make it ever more important that private planes and regular operating passenger aircraft be equipped with up-to-date, reliable two-way radio, if high standards of safety are to be maintained. One important factor is . . ."

"A FOOLPROOF POWER SUPPLY FOR AIRCRAFT RADIO OPERATION"

Colonel Casey, Electronic Laboratories has long been aware of the need for reliable power supplies especially adapted for aircraft use. One of E-L's exclusive developments along this line involves vibrators operating in parallel which assures a reserve power source for extra protection. These Vibrator Power Supplies—both light and heavy duty—are specially designed for complete reliability at very high altitudes.

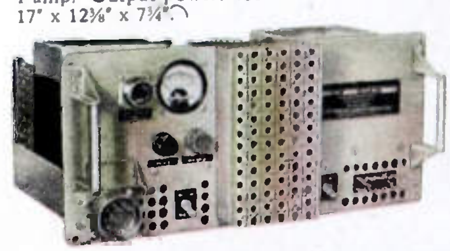
The life of E-L Vibrator Power Supplies is far beyond the customary overhaul requirement. With these units maintenance time is cut to a minimum—only a small fraction of the time previously required.

Other E-L developments for the aircraft field include units for flashing wing lights and for instrument panel illumination. This equipment has wide application for the light plane field as well as for large aircraft.

The economy and versatility of Vibrator Power Supplies are also available to the marine field—where units have been designed to provide fluorescent lighting, radio-telephone operation and electrical appliance use—as well as many other fields where it is necessary to convert current to specific voltage and type requirements . . . Let E-L engineers consult with you on your power supply problem.

STANDARD POWER SUPPLY MODEL SC-1096

Model SC-1096 is a typical E-L Vibrator Power Supply which meets the requirements of aircraft radio use. This unit was designed for the Canadian Signal Corps to operate radio transmitters. Input voltage: 12 volts DC, or 110-117 volts AC at 50-60 cycles. Output voltage: 2000 volts at 125 ma., 400 volts at 25 ma., 250 volts at 10 ma., 250 volts at 5 ma., 10 volts at 5 amps., 12 volts at 1 amp. Output power: 480 watts. Dimensions: 17" x 12⅜" x 7¾".



Electronic LABORATORIES INC.
INDIANAPOLIS

VIBRATOR POWER SUPPLIES FOR LIGHTING, COMMUNICATIONS, AND ELECTRIC MOTOR OPERATION • ELECTRIC, ELECTRONIC AND OTHER EQUIPMENT

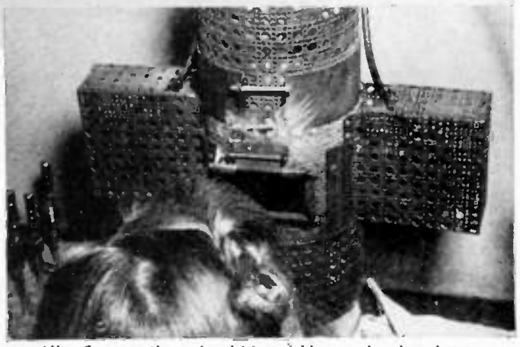
First exclusive manufacturer of short wave radio equipment to receive the coveted Army-Navy "E" Award for the fifth time . . . the result of the continued and untiring devotion to duty of the company's 1,500 employees.

hallicrafters

THE HALLICRAFTERS COMPANY · MANUFACTURERS OF RADIO AND ELECTRONIC EQUIPMENT · CHICAGO 16, U. S. A.

Builders of the famous SCR-299

welding with a paint brush?



Alloy flows easily and weld is quickly completed under arc.

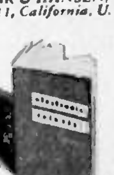
To solve a difficult welding problem, Eimac laboratory technicians compounded a welding alloy that could be applied with a paint brush. The alloy flows easily under an arc to complete the weld, yet subsequent heating to temperatures as high as 2900 degrees Centigrade will not destroy the weld.

Such is but an example of the application of the Science of metallurgy in the "science behind the science of electronics." The extent to which Eimac Engineers went to solve this relatively small problem reveals two important facts:—(1.) The thoroughness of Eimac Engineering, and (2.) The completeness of their engineering facilities. The leadership which Eimac tubes enjoy throughout the world in all phases of electronics is attributable to the soundness of this engineering.

Performance of any electronic equipment is a direct reflection of the performance of its vacuum tubes. Hence it is advisable for users and prospective users of electronics to look first to the vacuum tube requirements. Because Eimac makes electron vacuum tubes exclusively their advice to you is unbiased and can be of great value. A note outlining your problem will bring such assistance without cost or obligation.

EITEL-McCULLOUGH, INC., 870 San Mateo Ave., San Bruno, Calif.
Plants located at: San Bruno, California and Salt Lake City, Utah
Export Agents: FRAZAR & HANSEN,
301 Clay St., San Francisco 11, California, U. S. A.

Write for your copy of Electronic Telesis—a 64 page booklet fully illustrated—covering fundamentals of Electronics and many of its important applications. Written in layman's language.



Follow the leaders to

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

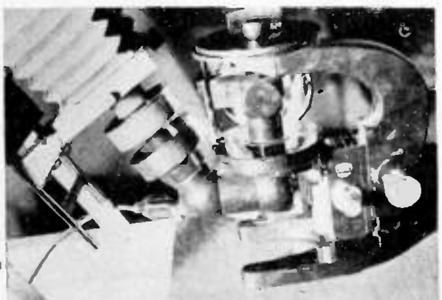
870

The Science Behind the Science of Electronics

is the focusing of all branches of science upon the development and improvement of electron vacuum tubes.

SPECTROGRAPH... Analysis determines exact characteristics of metals to be joined.

METALLURGY... Compounding special alloys of metals.



OPTICS... For studying the effects of processing.

ELECTRONICS... Welded elements in electron vacuum tubes withstand tremendous heat.

Here's an ESSENTIAL TOOL for Radio-Electronic Engineers, Designers, Equipment Builders, Manufacturers...

NEW 152-PAGE CAPACITOR CATALOG

Contains Application Engineering Data and Separate Sections on MICA, PAPER, and ELECTROLYTIC CAPACITORS

● Why essential? That's a big statement. Let us qualify:

This new Aerovox Catalog contains that information which is essential to those who design and build radio-electronic equipment. Here is general and specific engineering data on capacitors and their applications; detailed specifications on various types; listings of recommended types and ratings; special notes covering special features and special types; color codes; etc.

For greater convenience, the catalog is divided into four sections, each with its tab-indexed cover. These sections comprise Mica Capacitors, Application Engineering Data, Paper Capacitors, Electrolytic Capacitors. The plastic binding permits pages to lie absolutely flat.

In preparation for a year and a half—involving widespread gathering of data and intensive compilation—this combination manual-catalog represents an outstanding contribution to the working library of the radio-electronic engineer and executive. It was prepared BY engineers FOR engineers; contains absolutely no advertising—just information on capacitance and capacitors. And because of cost, its circulation is strictly limited to engineers and executives.

● Write for Your Copy...

If you are engaged in designing or building radio-electronic equipment of recognized standing, write on your business letterhead for your registered copy. Also submit your capacitor problems and requirements for our collaboration.

AEROVOX Capacitors

INDIVIDUALLY TESTED

AEROVOX CORPORATION, NEW BEDFORD, MASS., U. S. A. · SALES OFFICES IN ALL PRINCIPAL CITIES

Export: 13 E. 40 ST., NEW YORK 16, N. Y. · Cable: 'ARLAB' · In Canada: AEROVOX CANADA LTD., HAMILTON, ONT.

HYTRON has made them all!

The march of Hytron receiving tube progress down through the years is fascinating. One looks back on tubes, tubes, and more tubes: battery, AC, AC/DC, diodes, triodes, pentodes, beam tetrodes, multiple purpose types, G's, MG's, BANTAM GT's—and now the miniatures. Price and size have been drastically cut; quality and performance, amazingly improved.

Hytron has made them all. Its long and varied experience is priceless in a complex industry where probably never will all the answers be known. In making radio tubes, painfully acquired practical experience must supplement the formulae of science.

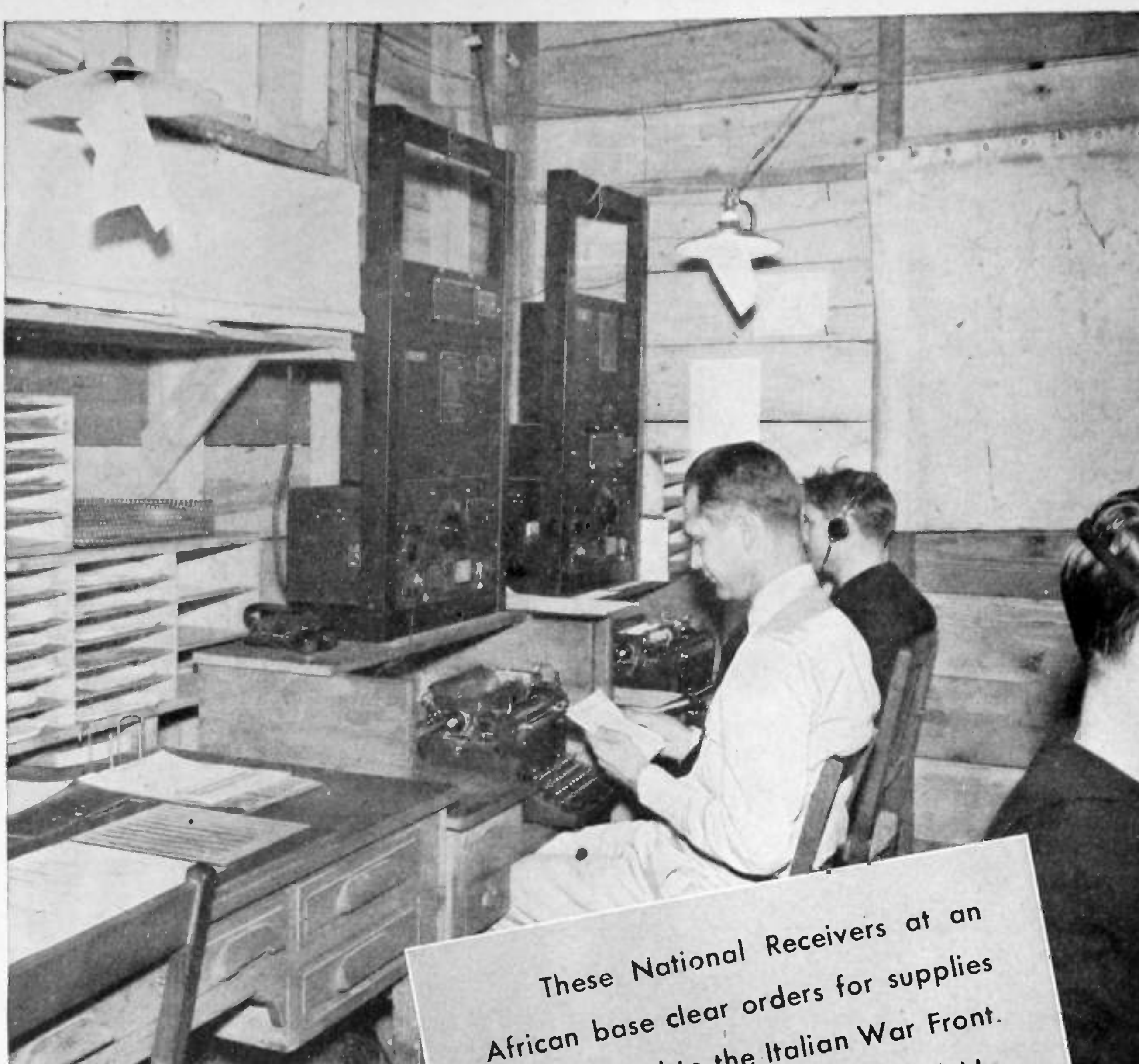
With an eye to present and future, Hytron is concentrating its production of receiving tubes on preferred BANTAM GT types needed for war—for today's civilian replacements—and ultimately for post-war. Its wartime activities are teaching Hytron new techniques of miniature production. Many potentially popular Hytron miniatures are in development. Typical American dissatisfaction with anything but perfection continues; the parade of Hytron receiving tubes marches on.

OLDEST EXCLUSIVE MANUFACTURER OF RADIO RECEIVING TUBES

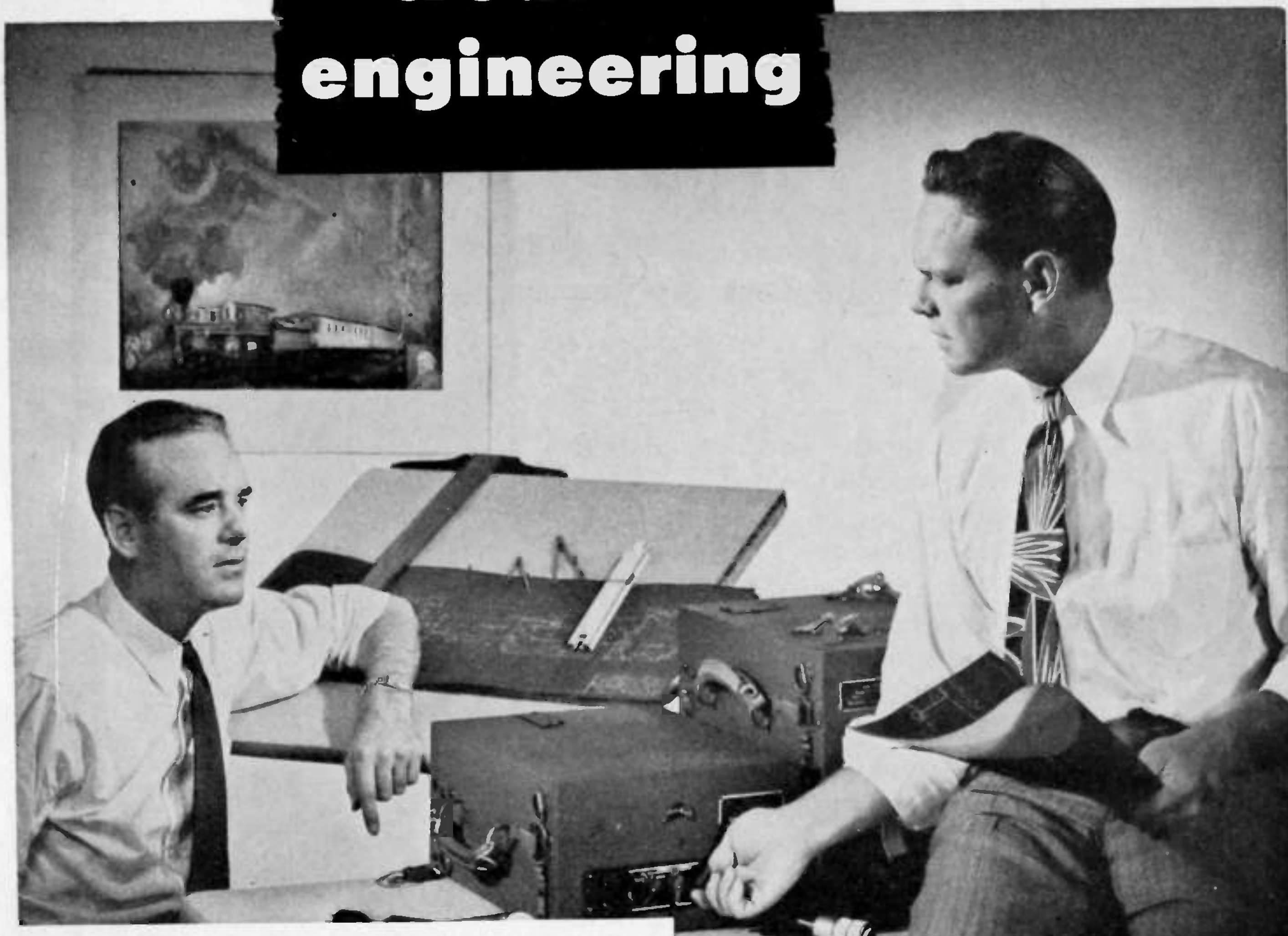
HYTRON CORPORATION ELECTRONIC AND RADIO TUBES

SALEM AND NEWBURYPORT, MASS.

BUY ANOTHER WAR BOND



creative engineering



The electronic engineer has more than a testing and research job. His is a creative job, too. From his fertile mind come the great new ideas for the electronic equipment which is helping to defeat the enemy and which will mean a glorious peacetime era when peace is assured. Most all industries will benefit from the highly specialized technical and scientific knowledge of the electronic engineer and the discoveries he has made.

Raytheon is proud of its part in the immeasurably important role that advanced electronic equipment is playing in winning the war. When peace comes, Raytheon's research and wartime production knowledge will be used to doubly protect the electronic equipment requirements of post-war radio and industrial products manufacturers, and to assure Raytheon's continued leadership in the electronic era.

ARMY-NAVY "E" WITH STARS
Awarded All Four Divisions of Raytheon for Continued Excellence in Production

RAYTHEON
Raytheon Manufacturing Company
ELECTRICAL EQUIPMENT DIVISION
Waltham and Newton, Massachusetts

DEVOTED TO RESEARCH AND THE MANUFACTURE OF TUBES AND EQUIPMENT FOR THE NEW ERA OF ELECTRONICS

PRECISION MADE FOR PRECISE PERFORMANCE

and

PROVED IN USE!

There is no question about AAC crystals meeting the most exacting requirements under severe operating conditions. Their reliability has been tested and proved a thousand times over . . . in battlefront service to the armed forces . . . in helping to keep the communication systems of many leading airlines working efficiently . . . in meeting the quality demands of radio manufacturers. The list of users of AAC crystals shown below is a tribute to the engineering skill and fine manufacturing facilities behind AAC crystals.

Braniff Airways, Inc.
Chicago & Southern Air Lines, Inc.
National Airlines, Inc.
Northwest Airlines, Inc.
Pan American Airways System
Pan American-Grace Airways, Inc.
Pennsylvania-Central Airlines Corp.
Transcontinental & Western Air, Inc.

Colonial Radio Corp.
Columbia Broadcasting System, Inc.
Stewart-Warner Corporation
Western Electric Company, Inc.
Zenith Radio Corporation

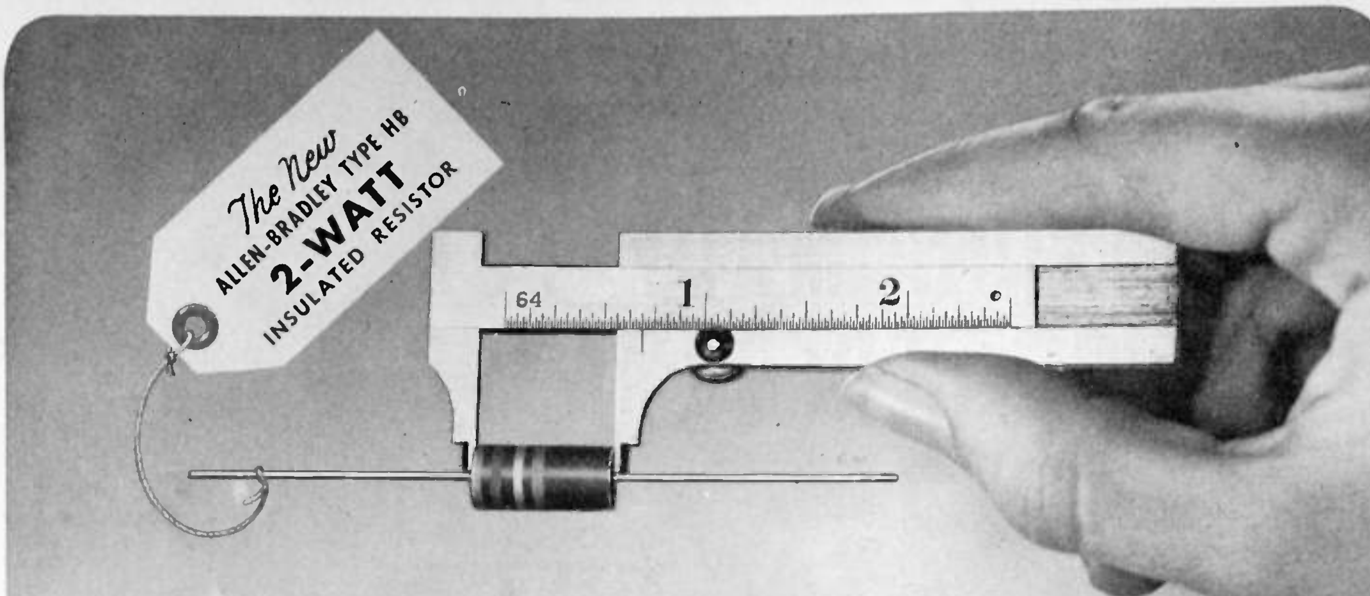
Remember, crystal production is only one of AAC's services to the aviation and electronics industries. The production of airborne and ground radio equipment at the rate of more than 30 million dollars yearly for U. S. government and leading airlines demonstrates the wide scope and high rating of AAC manufacturing ability.

E-134

ACCESSORIES CORPORATION

ELECTRONICS • ENGINEERED POWER CONTROLS

New York, N. Y. Burbank, Calif. Cable Address: AACPRO



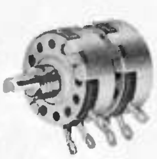
It's the Smallest 2-Watt Fixed Resistor

BRADLEYOMETER

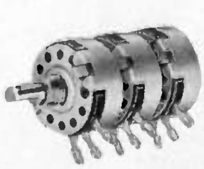
The World's Finest Continuously Adjustable Resistor

The only continuously adjustable composition type resistor (only 1 inch diameter) having a rating of 2 watts with substantial safety factor. Has solid molded resistor unit .. not a film, spray, or paint type. Any resistance-rotation curve available.

Type JS Bradleyometer with built-in line switch. Not affected by heat, cold, or moisture.



Type J Bradleyometers may be used singly or assembled into multiple controls.



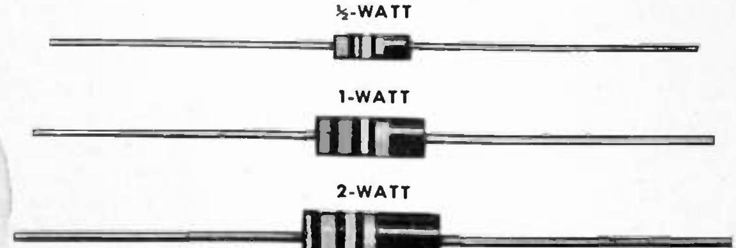
Low resistance carbon brush makes contact with surface of molded resistor.

ONLY $\frac{11}{16}$-inch long .. and $\frac{5}{16}$-inch diameter .. those are the remarkably small dimensions of the NEW Type HB Bradleyunit. It is the smallest 2-watt insulated fixed resistor ever produced, but you can use it safely right up to its listed rating. You don't have to derate it for even the toughest application.

The Type HB 2-watt Bradleyunit will pass all American War Standard tests: It is outstanding in its humidity and temperature characteristics. It matches in dependability and fine appearance the Allen-Bradley ½-watt and 1-watt Bradleyunits (see below) which are recognized as "tops" by all radio and radar men.

Available in R. M. A. standard values from 10 ohms to 0.47 megohms in tolerances of 5, 10, and 20 per cent. Specify the Type HB 2-watt Bradleyunit and be safe in your engineering.

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



A-B ALLEN-BRADLEY

FIXED & ADJUSTABLE RADIO RESISTORS

QUALITY

Something to Remember

about having your CAPACITOR SPECIFICATIONS MATCHED

SPRAGUE CAPACITOR TYPES

Dry Electrolytic
Paper Dielectric
Mica Dielectric
Power Factor Correction
Motor Starting
High Voltage Networks
Radio Noise Suppression Filters, etc., etc.

In designing or producing a radio or electrical product, there are plenty of things to think of besides capacitors. Moreover, unless you've specialized, it's difficult to keep fully abreast of modern capacitor developments. That's why we make this suggestion:

Write today for a supply of Sprague Sample Request Forms. Then, as capacitor applications arise, use these forms to send full details to Sprague engineers. Let them make suggestions. Benefit from their broad experience, as well as from the fact that Sprague regularly produces dozens of standard Capacitor types, plus hundreds of adaptations and special units.

Such a request places you under no obligation to buy the recommended type. It simply assures you of specialized attention in the selection of an important component on which there are many factors to consider—angles which cannot always be cataloged completely or promptly, or which cannot be uncovered in any other way than through this personalized engineering service.

Write today for a supply of Capacitor Sample Request Forms.

SPRAGUE ELECTRIC COMPANY, North Adams, Mass.
(Formerly Sprague Specialties Co.)

A typical group of Sprague Dry Electrolytic Capacitors designed to match special specifications.

SPRAGUE

CAPACITORS • KOOLOHM RESISTORS

T. M. REG. U. S. PAT. OFF.

Casting the International Meter Rods in Paris 1874. The degree of accuracy attained 1/10,000,000 of a quadrant of a terrestrial meridian.

WHO SETS THE *Quality Standard* FOR TRANSMITTING TUBES

IN every art or craft, the work of some acknowledged master sets the standard.

Since 1934 UNITED has won recognition by specializing exclusively in the engineering, design and building of transmitting tubes which are unchallenged for excellence. UNITED tubes excel in every electronic application . . . including radio communication, physiotherapy, industrial control and electronic heating. In these and other applications, tubes by UNITED continue to win top honors for uniformly dependable performance.

In communication equipment for airlines, commercial broadcasting, police radio stations and other vital civilian services, UNITED transmitting tubes set the standard. Accept nothing less than UNITED quality tubes for your requirements.

Order direct or from your electronic parts jobber.

UNITED

TRANSMITTING TUBES

UNITED ELECTRONICS COMPANY

NEWARK, 2 New Jersey

Transmitting Tubes EXCLUSIVELY Since 1934

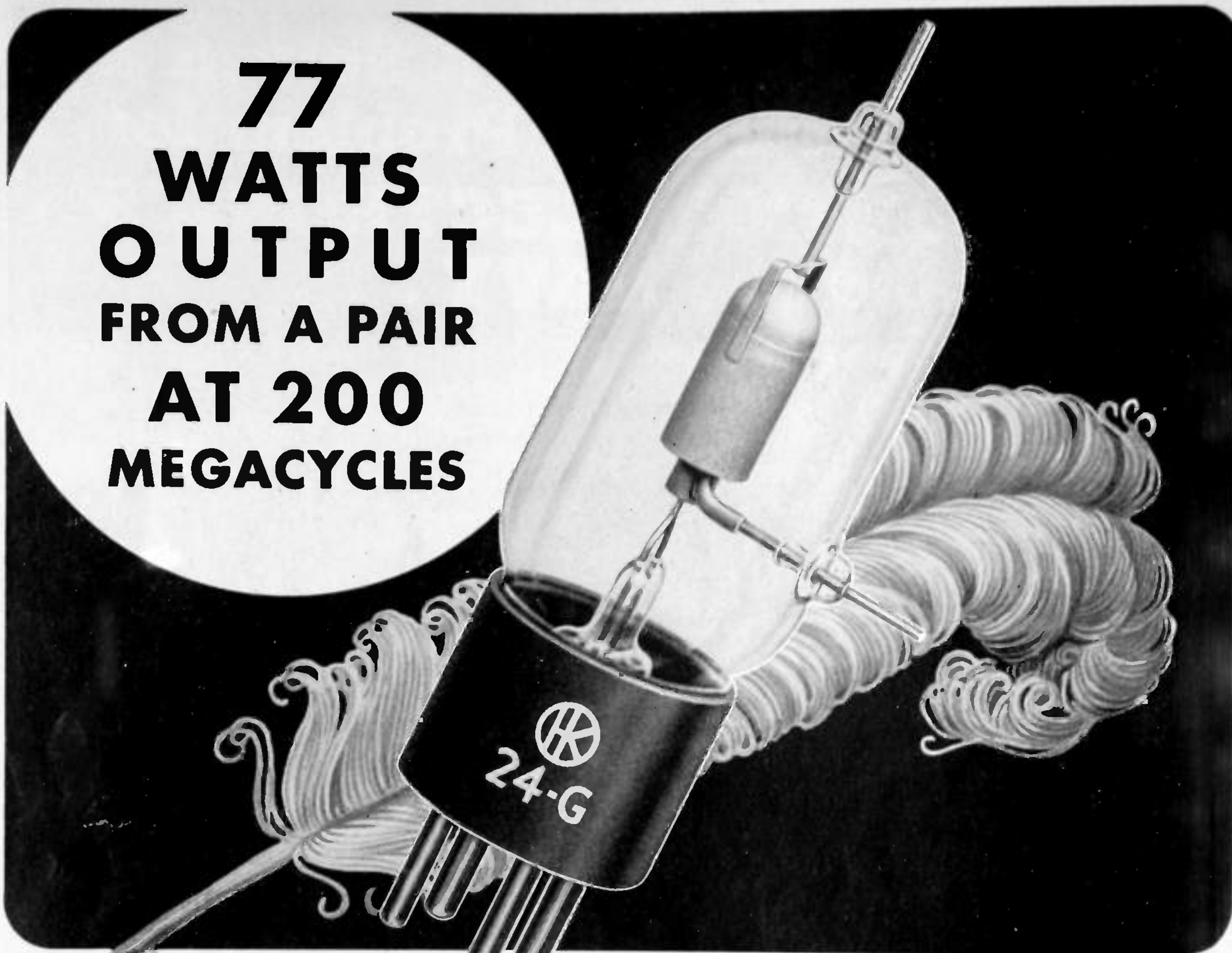
Another big rush on Long Distance lines this Christmas . . .

It was a big rush last year. It may be even bigger this Christmas.

So please help keep Long Distance lines clear for essential calls on December 24, 25 and 26.

War still needs the wires — even on holidays.

BELL TELEPHONE SYSTEM



H & K developed this *featherweight* to pack a wallop in the VHF region

The only thing that's small about this 4½-inch, 1½-ounce Gammatron is its size. Heintz and Kaufman engineers originated and perfected this powerful little tube to put out a 77 watt signal from a pair at 200 Mc. as a Class C unmodulated amplifier... 116 watts at 100 Mc. Even at peak frequency, 300 Mc., a pair of HK-24G Gammatrons develop a remarkable 44 watts.

The high efficiency of the HK-24G in the VHF region results from (1) the long, capped tantalum plate, typical of Gammatrons, which confines the entire electron stream for useful output, and (2) the fact that this grid is closely spaced to the filament for short electron time-flight.

The HK-24G triode is easy to neutralize, and parasitic oscillation is avoided, because the inter-electrode capacities are very low, and the grid and plate leads are short. For typical operating ratings of the HK-24G as an r. f. power amplifier, audio amplifier, crystal oscillator, doubler, or tripler, write today for data.

HK-24G MAXIMUM RATINGS

Power Output Class "C" R. F.	90 Watts
Plate Dissipation	25 Watts
Amplification Factor	25
Plate Voltage	2000 Volts
Plate Current	75 MA
Grid Current	25 MA
Frequency	300 MC
INTER-ELECTRODE CAPACITIES	
C Grid-Plate	1.6 UUF
C Grid-Filament	1.8 UUF
C Plate-Filament	0.2 UUF
FILAMENT	
Volts, 6.3	Amperes, 3

LOAN YOUR DOLLARS DONATE YOUR BLOOD FOR EARLY VICTORY

HEINTZ AND KAUFMAN LTD.
SOUTH SAN FRANCISCO • CALIFORNIA
Gammatron Tubes


CALIBRATED
Through the development of our own highly specialized calibrating equipment Hammarlund engineers have made possible mass production of variable capacitors with accuracies comparable to laboratory standards.
HAMMARLUND
THE HAMMARLUND MFG. CO., INC., 460 W. 34TH ST., N. Y. C.
MANUFACTURERS OF PRECISION COMMUNICATIONS EQUIPMENT

In QUARTZ CRYSTALS, the most significant advancements have been introduced by Bliley

This is a message from Bliley to the thousands of amateurs and professional engineers who are now serving their country in the armed forces and in essential communications industries. Bliley "grew up" with them.

To these men and women Bliley crystals are still a familiar sight. They recognize, in the military crystal units used by our armed forces, many basic features that were pioneered by Bliley for application in peacetime services.

When tremendous production was demanded by our armed forces Bliley had the engineering background, the facilities and the production experience to provide a firm corner stone on which this volume production of radio crystals was successfully built. And, from the ranks of talented amateurs and radio engineers came a host of long-time friends who knew exactly how to use them.

But research has continued and experience has grown mightily to meet the challenge of war requirements. With the return to peace, and relaxation of wartime restrictions there will be better Bliley crystals for every application as well as new Bliley crystals for the new services that loom on the horizon. That's a promise.

To our old friends, amateurs and professional engineers, we say, "Look to Bliley for crystal units that embody every advanced development."

ARMY E NAVY

Bliley CRYSTALS

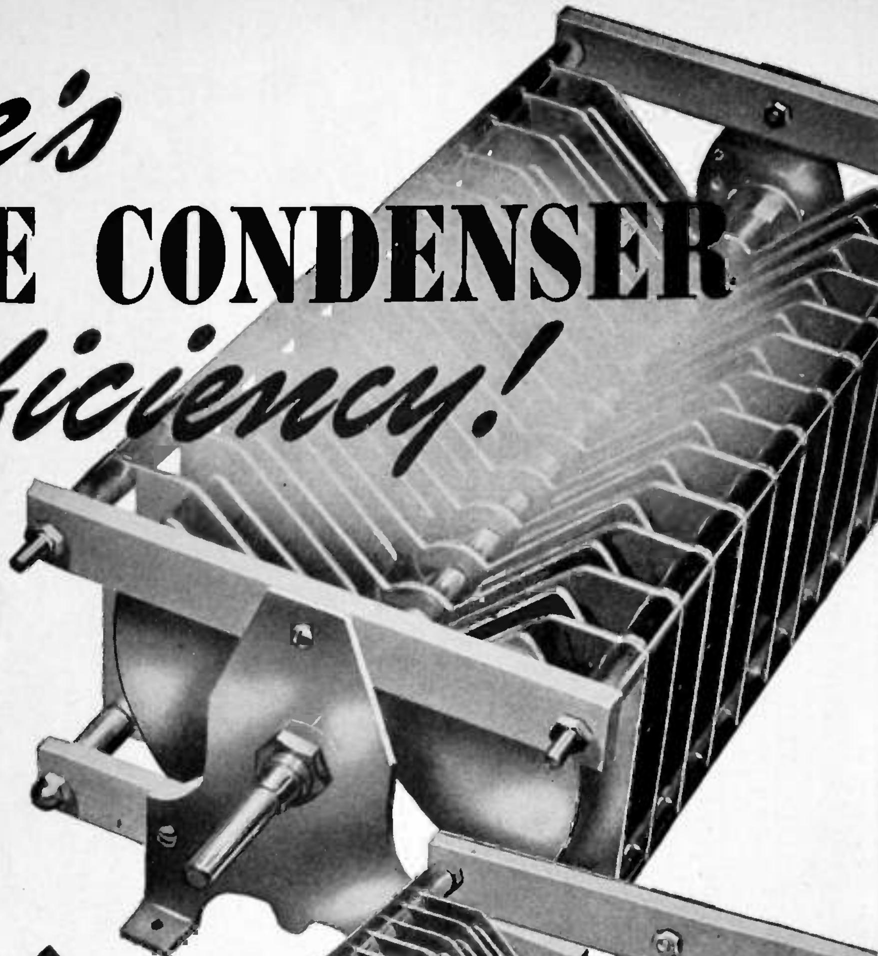
Do more than before . . .

buy extra War Bonds

BLILEY ELECTRIC COMPANY

UNION STATION BUILDING · ERIE, PENN.

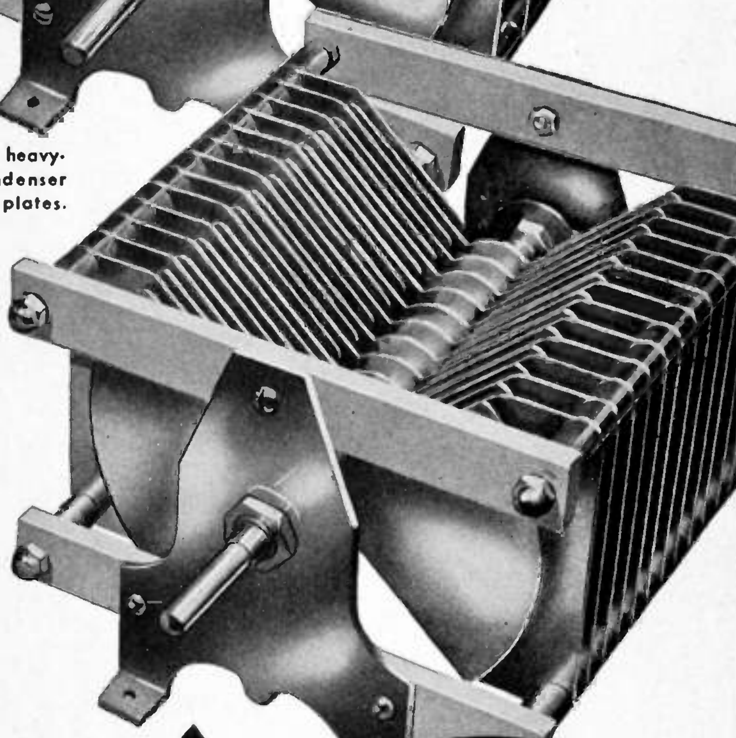
Here's VARIABLE CONDENSER *Efficiency!*



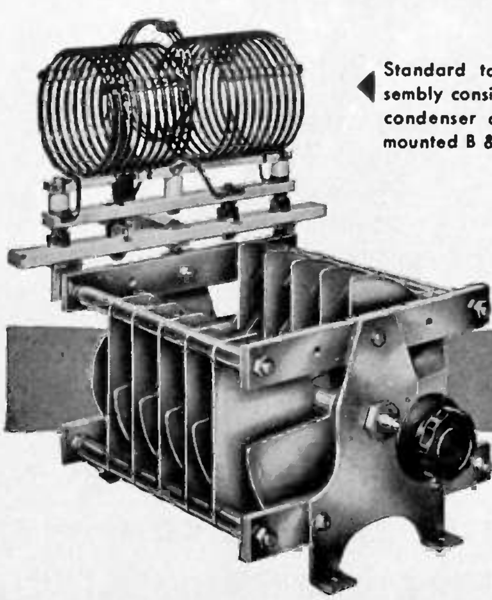
- Perfect electrical design symmetry.
- Built-in neutralization.
- Unexcelled mechanical construction.
- Built-in coil mountings with lead lengths at an absolute minimum.
- Half the length of conventional dual condensers.
- Unexcelled for use in balanced single-ended or push-pull circuits.

A B & W heavy-duty Condenser with 1/8" plates.

Write for new Catalog 75-C on B & W Type CX heavy duty variable condensers



Typical standard Type CX Condenser with 1/16" plates.



Standard tank circuit assembly consisting of B & W condenser and integrally mounted B & W coil.

B&W

AIR INDUCTORS • VARIABLE CONDENSERS
ELECTRONIC EQUIPMENT ASSEMBLIES

BARKER & WILLIAMSON

Dept. IR-114, 235 Fairfield Ave., Upper Darby, Pa.

Export: LINDETEVES, INC., 10 Rockefeller Plaza, New York, N. Y., U. S. A.

This G. I. has an important call to make the instant he lands. For the next steps in the gigantic Air Invasion depend upon the reports he sends back . . . on the instructions he receives.

Fortunately, there will be no crowded circuits, no "busy" signals, for on his back this airborne trooper carries the means for instant, dependable Communications. In its way, it's as expertly designed and built as the huge Transport he has just left, as the automatic rifle that he clutches . . . designed and built to give the greatest possible measure of service under the most punishing conditions. It's one of the reasons why our troops are called the most superbly equipped in the world.

★ ★ ★

Supplying Transformers, Coils, Headsets and special Electronic parts is the wartime job of Rola, pioneer manufacturer of Sound-Reproducing Equipment.

THE ROLA COMPANY, INC.
2530 SUPERIOR AVENUE • CLEVELAND 14, OHIO

ROLA

MAKERS OF THE FINEST IN SOUND REPRODUCING AND ELECTRONIC EQUIPMENT

Electronic Papers

This is a proposal that a still further increased number of papers dealing with electronic apparatus and methods shall promptly be submitted for publication in the PROCEEDINGS OF THE I.R.E. in order to promote the rapid development of the radio-and-electronic field and to place before the readers of the PROCEEDINGS the fundamental steps taken in that domain.

During the several decades of its existence, the contents of the PROCEEDINGS OF THE I.R.E. have faithfully mirrored the trends and accomplishments of current engineering within the scope of the Institute. Its pages have been at once a history of the art, a recital of current practice, and an introduction to future developments. The underlying policy continued in force, even in the troubled days of World War I. It remains unchanged in the far more turbulent period of World War II.

It is timely to redefine the scope of The Institute of Radio Engineers and accordingly of its PROCEEDINGS. Briefly, these interests cover the field of radio technique and its applications. This realm of thought has been termed the radio-and-electronic field. It naturally includes radio communication in all its aspects, both two-way and one-way. The latter type is represented by that major method of mass communication: radio broadcasting. Telegraphy, telephony, facsimile, teleprinting, and television are the broad method aspects of the radio field. Transmission, propagation, and reception of any form of electromagnetic waves—including the versatile extremely high-frequency oscillations—are necessarily involved.

But applied radio technique extends further, and into all of what may be termed the field of electronics. A wide variety of phenomena, practices, and devices have been included under that heading. Methods of intricate, high-speed, and unusually accurate control of physical effects have been involved. Many circuit elements have been drawn from the field of pure radio, with minor modification, to meet the design needs of electronic devices. Amplifiers, oscillators, detectors, and their associated circuit assemblies are normally used. Photocells, capacitance-sensitive systems, and even television equipment have found their way into electronic use. In fact, the heterogeneity of radio-and-electronic devices and methods is one of their distinguishing characteristics!

The PROCEEDINGS OF THE I.R.E. can and will take its proper place in contributing substantially to the development of all electronic aspects of its field. An increasing number of basic papers dealing with the corresponding topics will be found in its pages.

There will be required co-operation on the part of the membership of the Institute to maintain this publication policy in effective fashion. Accordingly, those workers who develop electronic devices or methods which are at this time without direct military significance are urged to prepare papers descriptive of their work and to submit these for publication in the PROCEEDINGS.

The PROCEEDINGS will always represent the integrated engineering thought, technical effort, and group loyalty of the members of the Institute. It will stand as a symbol of their professional aspirations and accomplishments. It is earnestly hoped that the Institute will find a prompt and major response to this appeal for the early submission of papers dealing with the electronic aspects of the field of engineering activity of the members and their Institute.

The Editor

Major General Harry C. Ingles

Major General Harry C. Ingles, who was appointed Chief Signal Officer of the Army on July 1, 1943, has been connected with communication work in the Army since the beginning of World War I and has had a wide and varied career in the Army.

He was graduated from West Point with a B.S. degree in 1914, and during the last war he was in charge of the training of Signal Corps officers.

Since the last war he has had various communication assignments, including Signal Officer, Philippine Division; Director, Signal Corps School; instructor in communication at the Command and General Staff School; Signal Officer, Third Army; and Signal Officer, Caribbean Defense Command.

Other important duties to which he has been assigned include War Department General Staff; Chief of Staff, Caribbean Defense Command, for which duty he was awarded the Distinguished Service Medal; and Deputy Commander, European Theater of Operations.

General Ingles is a graduate of the Army Signal School and the Army War College, and a distinguished graduate of the Command and General Staff School.

The electronic engineers, as well as the communication engineers, have played an outstanding part in the present world conflict. They have both contributed a host of devices of significance to the Military Services. It is therefore with deep gratification that the Institute presents to the readers of the PROCEEDINGS OF THE I.R.E. a guest editorial dealing with the work of the members of the Institute and coming from the pen of the Chief Signal Officer of the United States Army, Major General Harry C. Ingles. This message came with the best wishes of General Ingles to the entire membership of The Institute of Radio Engineers—and these wishes are certainly heartily reciprocated.

The Editor

Radio-and-Electronic Engineers in War and Peace

MAJOR GENERAL HARRY C. INGLES

When the history of World War II is written, it will be found that although little publicity was given to the work engaged in during hostilities by radio and electronic engineers, it was the painstaking research activities and patriotic devotion to duty of these brilliant scientists which materially hastened the final Allied victory.

Following on the heels of the Pearl Harbor attack, our country called for help, and many leading radio-and-electronic engineers, most of them members of The Institute af Radio Engineers, were prompt in their response. Today the United States is the communications center of the world and much of the credit must go to the excellent co-operation of these men of science.

In these days of whirlwind warfare, with entire armies moving at unbelievable speed, signal communications are of paramount importance in directing our gigantic offensives. The Signal Corps, whose principal mission is to insure swift and reliable communication among all elements of the Army from the high command in Washington to the most advanced outpost, employs every serviceable means to achieve that accomplishment.

But it is in the field of radio and electronics that the Signal Corps has attained pre-eminence in signal communications. Many amazing items of signal communications equipment have resulted from the research activities of radio-and-electronic engineers in co-operation with Signal Corps engineers. For the time being much of this equipment must remain a military secret. However, members of The Institute of Radio Engineers may well feel proud of their contribution to the successful performance of this equipment on battlefields in every quarter of the globe, and to the winning of the great conflict now raging. Without their scientific aid, the magnificent victories now being won by our forces might not have been possible.

The Signal Corps has trained thousands of men in the basic principles of radio-and-electronic engineering in order to provide personnel to operate and repair the intricate and astounding signal equipment now helping our men to win victories all over the world. Radio-and-electronic engineers, by lending their knowledge of this vital science, helped to improve and perfect this vast training program.

Thus the radio industry will have a large reservoir of trained personnel upon which to draw for its postwar expansion, which will eclipse anything it had attained prior to the opening of hostilities in the Far East.

Radio-and-electronic engineers now have a big job in helping us to win the war. But they will also have a job after victory in helping to set up new applications of the devices they aided in developing for military purposes. But what is more important, members of The Institute of Radio Engineers, when peacetime comes, can render a patriotic service to our country by helping it to grow even stronger, through science, so that no aggressor, or combination of them, may ever again threaten our security.

Frederick B. Llewellyn

Chairman, Papers Committee

Frederick B. Llewellyn was born in New Orleans, Louisiana, on September 16, 1897. In 1915 Dr. Llewellyn took a course at the old Marconi School for Wireless Operators. Off and on, Dr. Llewellyn put in about three years in the merchant marine, plus the better part of a year in the Navy during the 1917–1918 outbreak.

He was graduated from Stevens Institute of Technology in 1922, where he took special courses under Professor Alan Hazeltine. A year was then spent as laboratory assistant to Dr. F. K. Vreeland and in 1923 he joined the technical staff of the Western Electric Company, later transferring to the Bell Telephone Laboratories when it was formed in 1925. His work was then concerned with the long-wave transatlantic telephone, operating through Rocky Point, L. I. From 1924 to 1928 he attended graduate classes at Columbia and in 1928 received the Ph.D. degree.

In 1929 the ship-to-shore telephone service was inaugurated with the *S. S. Leviathan* as the first to open for public service. Dr. Llewellyn was one of the engineers who carried out the development of the shipboard installation and made a number of voyages on the famous vessel. Ten years later a reunion luncheon was held at which Commodore Cunningham was presented with the telephone handset which had been in his cabin at the opening, when he was skipper of the ship.

On shore once more, Dr. Llewellyn's next work was the investigation of noise in vacuum tubes and of constant-frequency oscillators. This was followed by a study of the action of vacuum tubes at very high frequencies. In 1936 he was awarded the Morris Liebmann Memorial prize for his results on high-frequency electronics and on constant-frequency oscillators.

A member of the Electronics Committee for many years, Dr. Llewellyn was especially active in connection with the Electronics Conferences which were held for the years just preceding the war. With the retirement of Dr. William Wilson as Chairman of the Papers Committee, he succeeded to that post. For the past two years he has been on the Executive Committee, where his special assignment is to promote the welfare of the technical committees. He became an Associate Member of the Institute of Radio Engineers in 1923 and was transferred to the Fellow grade in 1938.

Philosophy of Design*

The Foundation for Better Planning

C. M. ASHLEY†, NONMEMBER, I.R.E.

Summary—Success of an industrial research and development organization depends not only upon the ability and intelligence of its members and on the effectiveness of their organization. Equally important is a proper working philosophy as the guide to action for each individual and for the group as a whole. The development engineer must deal with nature in a most imperfect state where theory is frequently hidden from sight by the complexity of interactions involved. Problems with which he wrestles are usually too complex for exact analysis. Experience teaches the development man things which his intellect would never have told him. He learns the proper balance between daring and caution, idealism and realism, theory and practice. His way of thinking must be pragmatic in character, based upon an evaluation of risks and the probabilities of a given situation.

This Thing Called Perfection

THE perfectionist is never happy as a development engineer. He quickly learns that perfection in any detail is difficult to obtain and requires an inordinate amount of time. He is soon forced to one of two alternatives. Either he perseveres, seeking perfection, in which case he ceases after a time to be a useful development engineer, or else he gives up his ideal of perfection, in which case he is no longer a perfectionist. At the other extreme is the man who is easily satisfied with an imperfect achievement and never realizes the possibilities of the thing which he is developing. Less complacent competition sweeps past this man.

Perhaps the ideal attitude is that of the deferred perfectionist. While never wholly satisfied with present forms, he realizes perfection is an objective which cannot completely be attained and is content to strive for worthwhile improvements. The problem of deciding when a development has reached a practical stopping point requires fine judgment. The design must be viewed objectively from the point of view of both the user and the salesman. Two questions must be asked: First, is the equipment developed commercially practical? Second, have possibilities of trouble been reasonably eliminated?

One reason why perfection cannot be taken too seriously is that it doesn't stay put. At best it is a mental image. Too often the engineer finds that his mental image has no reflection in reality, that a perfectly conceived and executed design leaves the field cold when some purely practical objection, such as cost or lack of market, acts as an insuperable bar to acceptance. Another quality of perfection is its growth. As progress is made our imagination reaches out still further ahead. Our ideas of perfection in equipment are constantly being tempered and conditioned by changing outside influences such as customer reaction, practical workability, or competition.

So the wise development man recognizes perfection as that something within himself which makes him dissatisfied with present forms, rather than an absolute objective. He learns to control this dissatisfaction to yield maximum returns for the time and money with which he has to work.

When Trouble Comes

Since perfection is never achieved, the development engineer is constantly beset by troubles. Equipment design is a strange mixture of theory and practice and often the theory comes only as the rationalization of recognized practice. In many cases it is only by repeated trials of a new design element that success can ultimately be won out of failure. Even the minor modification of a design in a thoroughly explored field may be beset by trouble. Consider the new model of an automobile, as an example. Let the motor manufacturer change anything more fundamental than the decoration on the hood and he brings down on himself a host of "weaknesses" despite endless trials in the laboratory, proving ground, and on the road. If this can happen, how much greater is the danger of trouble in a field not nearly so well stabilized nor able to give a new design adequate advance trial? What chance of being free from troubles has a new design, even when relatively simple, when put out with no field trials at all?

Trouble has another characteristic. No matter how successful 999 of 1000 elements of a machine are, if the one remaining part gives trouble that is all that matters. A man may have a car whose motor functions perfectly but he is still thoroughly annoyed by a weak ignition system, a short-circuited starter, or a grabbing clutch. Yet the "bugs" in that car may amount to only one hundredth of one per cent of the design problems which have been solved successfully.

What attitude must be taken? First, trouble must be expected from any change, however small. Second, the likelihood of trouble increases with the magnitude and with the novelty of the change. Third, the chances of catching the trouble in the laboratory stage depend upon the extent and intelligence of the proof tests. Fourth, no amount of proof-testing will catch all of the troubles. Fifth, the wise general always lays his plans for a retreat before he starts his advance.

When a change is made, ask three questions: One, what are the chances of trouble? Two, how can the trouble be discovered? Three, what alternatives are there in case trouble develops? Regarding the third,

* Decimal classification: R004. Original manuscript received by the Institute, September 11, 1944. Published by permission of the author and *Product Engineering*, in which it was originally presented in volume 11, on pages 443–444, of the October, 1940, issue.

† Product Development Engineer, Carrier Corporation, Syracuse 1, New York.

perhaps there are other methods for achieving the same result that do not seem quite as cleanly designed but which may be less novel, thus safer. Again, the changed part may be subdivided so that replacement is less expensive. Or particularly easy access might be arranged to cut the cost of a field repair.

The role of the development engineer becomes very much like that of the actuary who tries to gage the magnitude of the risk and sets premiums accordingly. Where the production of a machine part is small, it may not be expensive to take large risks. Where the risk possibility is great, the production must not be permitted to grow too large before extensive tests have proved the new design and reduced the risk to a minimum.

One of the most difficult psychological problems is for a man accustomed to designing for small-quantity production, to shift to designing for mass production. Where before he had the utmost freedom in making changes immediately as experience dictated, now he must stop to consider questions of cost, interchangeability, field replacement, confusion in manufacturing and marketing, and a host of others.

There is one other aspect of trouble that certainly deserves mention. It seldom or never occurs where it is expected. This is popularly recognized and is not so difficult to understand when it is remembered that anticipated trouble is usually guarded against. It is the unanticipated trouble against which we cannot protect ourselves. Still, we know from experience that we must expect it and prepare to meet it from whatever quarter it may come—by keeping designs as flexible and adaptable as is in any way consistent with the factors of cost and results.

The Time Factor

Pure research does not generally recognize time as one of its limitations. Development, on the other hand, meets constant pressure from management to conform its projects to rigid time schedules. Frequently these schedules are dictated not by the time required to carry on the development in an orderly manner, but by the exigencies of the commercial situation, such as competition, production demands, sales needs. It is hard for people outside of the development group to understand why schedules cannot be set up and met, and it is equally hard for those within to set them up and meet them.

Any sort of schedule assumes the success of each step and of the development as a whole, for failure would inevitably retard the work. Actually, however, failure is the customary initial reward of development. In fact, design engineers meet with so many failures in this line of business that they have to be optimists by nature. Otherwise they wouldn't have the courage to keep plugging. Success comes as a rule out of a series of time-consuming failures.

Most developments must fulfill not only one objective, but dozens simultaneously, such as cost, power demand, weight, space occupied, accessibility, quietness, good appearance, and reliability. The failure to meet any one of these may result in failure of the design as a whole. After extensive study it may be found that the objectives are unattainable. They must then be restated and the work started all over again. It is not to be wondered, therefore, that development problems, even those along conventional lines, should be hard to schedule. As for the radically new things, schedules had best be forgotten until some success becomes assured.

Every orderly time estimate of a development is based upon the summation of the time estimates for each separate step. You may allow for failures by figuring on one, three, or five trials to reach a successful solution of a given step, but there is no assurance whatever that this will be the number actually required.

It is commonplace to observe how simple an accomplished result seems compared with the labor and circumlocutions by which it was reached. Experience seems to indicate that developments take about three times as long as there seems any good reason that they should take. But it does not do to set up a schedule which allows this extra time for each step, since then the development engineer unconsciously plans a more exhaustive study which uses up more than the time allowed. For the development as a whole this becomes cumulative. The best plan is to set up each step, giving it a reasonable allowance above the requirements visualized at the start of the development. Then, for the development as a whole, an extra time allowance as taught from experience should be made to cover the remaining contingencies.

Savings in time required to consummate a development can be made through more intelligent planning and execution, that is, better organization. This should be the constant aim of a development staff. Too often, however, the development engineer or director is swayed by commercial exigencies into feeling that in a particular case he can "beat the game." He is customarily disappointed. Even short-circuiting the usual procedure seldom helps him in the long run. Although he may be able to complete a development, he is later forced by unfavorable developments from the field to return to his unfinished task.

Time for design is one of the most important factors in the success of an industrial organization. There is no substitute for it. Both management and design engineers must give it due consideration in laying plans.

Development Planning

Planning is the lubricant that keeps a development organization running smoothly. Where proper plans are not made, the essential ingredient, time, is out of phase and the result is more likely to be chaos than accomplishment. The planning must be of three types. First, each development project must be planned so as to arrive at a satisfactory state of conclusion at the desired time. This involves the marshalling of resources and men and working out the time required. In general, all developments follow the same pattern, with variations caused by the magnitude of the design problems and production.

Next comes the planning of the whole development program. Here, all of the projects compete to some extent for the services of the shop, draftsmen, and engineers. In this program must be found some way to relieve the "bottlenecks" wherever they occur.

Finally, there is the problem of the long-term planning of the product engineering of the company. No company would think of operating without some sort of a budget, even though it knew that the budget would not be followed in all details. In the budget would be an account for the depreciation of all of the physical assets of the company: the machinery, the inventory, and the plant. Yet the designs of the products which it makes are seldom considered in depreciation. Some designs may have a useful life of ten or twenty years, but it is normal to expect a life of not more than one to three years before minor changes must be made, and no more than five before something fairly radical is required. In many lines the customer expects, and gets, a new design every year, even though the changes are mostly in the external appearance and gadgets, and the "revolutionary advances" come from the publicity department. It usually takes the better part of a year from the time a minor redesign is approved until it is rolling down the production line, and for a major redesign it may be one to five years, or more. For this reason, it is not enough to wait until some competitor brings out a new design and then try to match or better it.

What this adds up to is that a company, in order to stay in the running, must constantly apply fresh study and effort to each of its lines and must be ready to bring out of the laboratory, at the right moment, new models to keep abreast of competitive progress. For success in this, more time than seems necessary will be taken, troubles will bring their headaches, and the work probably won't be perfect when finished. It is the development man's unique privilege to expect, understand and admit these things. And development work can be soundly organized only by men who base their judgment and planning on the underlying abstract factors.

Ideas[1]

Ideas are the stuff from which new designs are spun. Everyone has had ideas, has put ideas into practice, and has listened to the ideas of others. Yet few people ever stop to consider just what an idea is. Its nature is generally misunderstood. For instance, it is commonly supposed that the number of ideas is limited, at least concerning any one subject, and that only a few persons are endowed with the mystic genius of idea creation. This is not so. Consider Rube Goldberg and his ilk and it is apparent that ideas can be legion.

[1] Published by permission of the author and *Product Engineering* in which it was originally presented in volume 11, on pages 511–512, of the November, 1940, issue.

Ideas are the impingement of imagination on experience. As such there is nothing mysterious or exclusive about their origin and there is no reason why anybody should not have them. They are likely to be original with one person to the extent that his experience or imagination is in advance of that of others. But ideas are the property of no man and are as free as air to those who would seek them.

What does distinguish some ideas from others is the directness and simplicity with which they reach their objective. The question is not "How can an objective be reached?", but rather, "How can it best be reached?" This point of view very evidently strips ideas of any inherent value. They retain value only as they are useful. By the same token, no particular credit redounds to the person who has an idea. Credit is due only to him who has a good idea.

There is no mental quality that permits anyone intuitively to select good ideas and only good ideas. Therefore, the problem of arriving at good ideas is one of elimination. This involves, in the first place, marshaling all of the ideas which can be conjured up on the subject. There is no reason why this procedure should not be orderly. After a little experience the ideas can be classified and all of the permutations and combinations exposed to view. The second step is to submit the various ideas to critical analysis.

Of the two steps, the second is the more difficult. One must be sure on the one hand that no hidden possibility is passed over lightly, and on the other hand that time is not wasted exploring unprofitable alleys of ideas. The quantitative attitude of approach toward this analysis is most valuable as it will eliminate the great mass of ideas which are qualitatively practical but quantitatively impractical.

An attitude which must be repelled is the proprietary one. It makes an idea no better just because I happen to have thought of it rather than you. It must derive its value without respect to who conceived it. Since the value of ideas can be proved by practice, it behooves each individual to see that his ideas are used only when they are superior to the ideas of others. There is always a suspicion that a person may not take an objective point of view in comparing his ideas with those of others. For this reason, it is frequently wise to get the opinion of some competent, disinterested person.

It frequently happens that an idea has to be presented in the proper form, that is, "sold" to the person with the necessary authority. It is not fair to suppose that ideas have self-evident merit which should immediately impress a superior, even when he is very receptive. On the other hand, it is important that the idea not be misrepresented.

Novelty

At first thought it might seem that a new design must have a great deal of novelty to be really valuable or worth while. The new, the miraculously different seems to be the thing which makes the headlines and attracts the attention. Yet how many times is the article which is radically different from all competitors the sales leader? Not many. True, when the advantages are clear and self-evident, then sales may flow to the novel product. But it lacks the mutual sales help of competitors which are much alike. A good example of this is the steam automobile. Basically a much simpler and more flexible machine than the conventional type, its patent protection and uniqueness proved its undoing.

Look around and consider how many things of a mechanical character which are considered indispensable represent the simplest, most dramatic approach to the problem. Then consider the vastly larger number of things which are the fruit of years of polishing what may basically be a very impractical idea. The automobile is perhaps the perfect example of this. Rube Goldberg himself could hardly have conceived of the automobile transmission, clutch, or ignition system. Before the automobile of today could be perfected it was necessary to establish and develop whole new industries, such as that of alloy steels. Every important part is the result of years of effort to achieve the best possible result without any fundamental change which would affect too many other parts.

Most progress in the line of machines comes as a gradual evolution of an existing type. There comes a time, however, when a radical departure must be made from previous forms if further progress is to be made. The new type is usually the survival of a whole series which have been tried and discarded. Naturally this process is expensive and is usually left to the little fellows who do not have much of a stake to lose. On the other hand, it pays every company to keep informed of progress and trends and occasionally to make a "scoop" by bringing out an advanced design.

What philosophical attitude can we have toward novelty? First, we can stop chasing will-o'-the-wisps; we can look to the present forms and study them to see how they can be made more perfect; we can accept something which may never reach the heights of ultimate perfection and refine it in detail to make it a highly workable design. Second, we must keep before us the ideal of a design which will not have the inherent limitations of the present type; we can and must be dissatisfied with present forms, striving for a simpler and basically better form. Third, we must appreciate the problems inherent in the attainment of the simpler form; the long search, the slow perfection to a usable state, the breaking down of commercial and psychological barriers to its use.

Harris and Ewing

People thought both of these ideas were ridiculous, but the one above was sublime. Knowing when not to laugh an idea out of existence calls for acute foresight and sound engineering judgment.

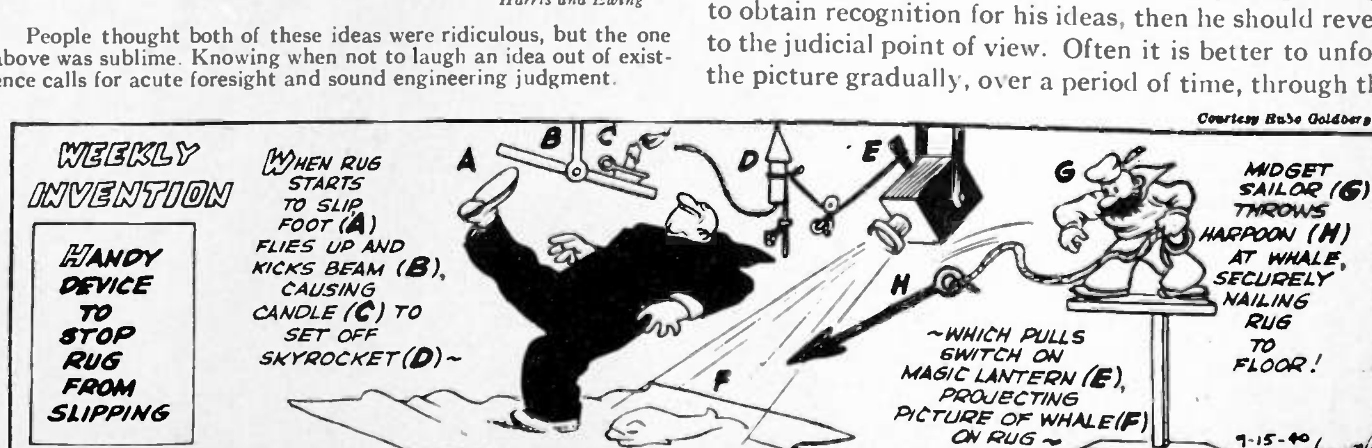
Selling the Idea

Equipment design and selling would seem to be as far apart as the poles. Nevertheless, there are times when the development man can serve his company best if he has the ability to "sell" his ideas to his superiors. It is a common belief that new ideas originate in the sales force in the field from whence they flow back to the development department, which puts them into workable form. Actually, this is seldom the case. The salesman must take a somewhat uncritical attitude toward the equipment which he sells in order to maintain his selling integrity. Naturally, he glosses over imperfections as long as possible.

On the other hand, the imaginative designer is painfully aware of the deficiencies of his design, even though he is not permitted to give voice to them publicly. More than that, he visions a product not only better in detail, but in basic conception as well.

The engineer need not take the role of the partisan in his presentation. His job is to show the relation of his ideas to others which might be considered. He should assume the attitude of an advocate only long enough to obtain recognition for his ideas, then he should revert to the judicial point of view. Often it is better to unfold the picture gradually, over a period of time, through the

Courtesy Rube Goldberg



medium of periodic suggestions. It frequently takes time to change mental patterns to meet new suggestions. But by means direct or devious, the engineer must somehow present the picture of the future in compelling terms.

Ideas and Organization

A development program must be organized in one of two ways; either one man or group must carry it through from beginning to end, or it must be passed successively from one specialized group to the next until it is finally completed.

For one man to carry on a project from beginning to end with success requires a most rare combination of abilities. It is an axiom that no man is at once a good beginner and a good finisher. To launch a development needs a man of boundless imagination. He should be able to think of all of the ways under the sun of doing a thing. His mind should range through all the possible and impossible ideas for accomplishing the desired end. Sometimes he will be able to distinguish between the possible and the practical. Often this must be done by someone with his feet more firmly on the ground. But even the "crackpot" inventor has his place at the beginning of a development.

Once the development passes its initial phases, however, this type of man usually loses interest. In his imagination it is already complete and perfect and his interest seeks out still other ideas. Such a man has not the patience to guide the development through its slow perfecting stages.

Here is needed a "hound" for detail, who can take all of the "kinks" out of the design, who can sharpen his pencil and whittle first dollars and then pennies out of the cost. He must be willing to prove the practicability of each part and of the whole design by exhaustive laboratory tests and field trials. Frequently, before the development is turned out as complete, quite a number of people must each take a hand in it in succession. More often than not the tooling and the introduction to manufacture is handled separately.

When one man is in a dominant position with respect to a development, he leaves the stamp of his personality upon the design. His weaknesses may be as evident as his strong points. Why then should carrying on the development under one man be considered? Because the other alternative is equally dangerous. When a design is passed on to a new group, something is lost in the transfer. Frequently the new group may approach the design from an entirely new point of view and lose much that was of value in the original design. The people dominating each step are likely to have their own pet ideas, which may find their way into the finished product to its detriment.

It is evident that there is no "royal road." Regardless of the method of organization, the project must depend for success upon the ability of the people who are to carry it on. Also, there must be no insulation, no barriers between the men or groups carrying on the development; each must be subjected to the same ideas and the same criticisms. This naturally indicates that there must be a common leader throughout the progress of the design.

How, then, are the disadvantages of this type of organization to be overcome? Most important of all, the leader must understand himself. He must know where his strength lies and where his weakness; where he can rely largely on his own judgment and where he must call on that of others. He must gather around him men who will complement his abilities in order to form a well-rounded group. He must know when to call for help outside of his group. Furthermore, this leader, by understanding his point of weakness, can gradually train himself to a rounded ability more nearly approaching that of the ideal development man. He can also learn a tolerance for diverse points of view which can contribute to the success of the development and can learn to accept even though he cannot sympathize with them.

There are, of course, many able men who, because of a too great one-sidedness or because of an insulation from the point of view of others, can never become leaders.

The administrator to whom the leader reports must provide a point of view which balances that of the leader. He must also see that the leader is surrounded by adequately complementary assistants. Thus, one of the most important aspects of the organization of development work is to study and train the aptitudes of individuals in order to fit them together into harmonious and well-rounded groups capable of carrying through a development from rough idea to finished product.

Correction

H. T. Friis, whose paper "Noise figures of radio receivers," appeared in the July, 1944, issue of the PROCEEDINGS on pages 419–423, has brought to the attention of the Editor an error in equation (15).

The formula appears as follows:

$$F_{ab}=(F_a+F_b)-1/G_a. \qquad (15)$$

The corrected formula is

$$F_{ab}=F_a+(F_b-1)/G_a. \qquad (15)$$

A Frequency-Dividing Locked-In Oscillator Frequency-Modulation Receiver*

G. L. BEERS†, SENIOR MEMBER, I.R.E.

Summary—**A new type of frequency-modulation receiving system is described in which a continuously operating local oscillator is frequency-modulated by the received signal. In an embodiment of the system which is described, the oscillator is locked in with the received signal at one fifth the intermediate frequency. With this 5:1 relationship between the intermediate frequency and the oscillator frequency, an equivalent reduction in the frequency variations of the local oscillator is obtained. Received signal-frequency variations of ±75 kilocycles are reproduced as ±15-kilocycle variations in the oscillator frequency. The frequency-modulated signal derived from the oscillator is applied to a discriminator which is designed for this reduced range of frequencies.**

The oscillator is designed to lock in only with frequency variations which occur within the desired-signal channel. The oscillator is, therefore, prevented from following the frequency variations of a signal on an adjacent channel. A substantial improvement in selectivity is thus obtained.

The voltage required to lock in the oscillator with a weak signal is approximately one twentieth of the voltage applied to the discriminator. Since this voltage gain is obtained at a different and lower frequency than the intermediate frequency, the stability of the receiver from the standpoint of over-all feedback is materially improved.

Other performance advantages and the factors affecting the operation of the sytem are discussed.

Frequency-modulation broadcasting is still in its infancy in terms of a nation-wide entertainment service. Until a large number of high-powered frequency-modulation broadcast stations are operating on a commercial basis, the major technical problems which are involved in the design of frequency-modulation receivers will not be fully appreciated. However, the experience which has already been gained from frequency-modulation broadcasting has indicated some of the problems which must be given serious consideration.

Probably the most difficult requirement to be met is that of obtaining adequate adjacent-channel selectivity. This problem was emphasized by a report on "Blanketing of High-Frequency Broadcast Stations" issued in 1941 by the Federal Communications Commission. High sensitivity is necessary in a frequency-modulation receiver to insure maximum performance. This requirement makes it difficult to provide the desired over-all stability without excessive shielding and other circuit complications. This problem has already been the subject of a great deal of engineering investigation and one of the solutions which has been proposed is the use of the double heterodyne type of superheterodyne receiver. A new approach to a solution of these problems is provided by a frequency-dividing locked-in oscillator frequency-modulation receiving system which has been developed.[1] It is the purpose of this paper to describe the new receiving system and to indicate some of the factors which affect its operation.

Description of System

Basically the operation of the system depends on producing, in the receiver, a local signal which is frequency-modulated by the received signal. The local signal is provided by a continuously operating oscillator. The received signal, after it has been amplified by conventional radio-frequency and intermediate-frequency amplifiers, is applied to the oscillator in such a way as to cause its frequency to change in accordance with the frequency variations of the received signal. In the particular applications of the system to be described in this paper, the oscillator is locked in with the received signal at one fifth the intermediate frequency. With this 5:1 relationship between the intermediate frequency and the oscillator frequency an equivalent reduction in the frequency variations of the local oscillator is obtained. Received-signal frequency variations of ±75 kilocycles are reproduced as ±15-kilocycle variations in the oscillator frequency. It should be noted that the locked-in oscillator operating at one fifth the intermediate frequency reduces the frequency deviation corresponding to any modulation frequency but does not change the modulation frequency. The frequency-modulated signal derived from the oscillator is applied to a discriminator which is designed for this reduced range of frequencies.

The output voltage of the oscillator is independent of the strength of a received signal, in fact, the same voltage is applied to the discriminator when no signal is being received as when the receiver is tuned to a near-by transmitter. This feature makes it unnecessary to employ the conventional arrangements for minimizing amplitude variations in the received signal.

The adjacent-channel selectivity of a conventional frequency-modulation receiver is determined by the selectivity characteristics of the radio-frequency and intermediate-frequency circuits. If these circuits do not provide sufficient selectivity, a local transmitter on a channel adjacent to the desired signal may produce, at the discriminator, a substantially greater voltage than is obtained from the desired station. Under these conditions the desired program will not be heard. In the new receiving system a novel principle is used to provide

* Decimal classification: R361×R414. Original manuscript received by the Institute, October 6, 1944. Presented, National Electronics Conference, Chicago, Illinois, October 6, 1944 (the Chicago Section of The Institute of Radio Engineers was one of the sponsors of the National Electronics Conference); Washington Section, Washington, D.C., October 9, 1944; New York Section, New York, N. Y., November 1, 1944.

† Radio Corporation of America, RCA Victor Division, Camden, New Jersey.

[1] United States Patent No. 2,356,201, filed February 12, 1942.

additional adjacent-channel selectivity. The oscillator is designed to "lock in" only with frequency variations which occur within the desired-signal channel. The oscillator is therefore prevented from following the frequency variations of a signal on an adjacent channel. A substantial improvement in selectivity is thus obtained by electronic means.

The "locked-in" oscillator arrangement which is used provides, under weak signal conditions, a voltage step up of approximately 20. In other words, the voltage required to lock in the oscillator with a weak signal is approximately one twentieth of the voltage applied to the discriminator. Since this voltage gain is obtained at a lower frequency than the intermediate-frequency, the stability of the receiver from the standpoint of over-all feedback is materially improved. This improvement is secured without the disadvantage of the additional image responses which are obtained with the double-heterodyne type of superheterodyne receiver.

One receiver arrangement is shown in Fig. 1. In this diagram the units which are heavily outlined are those which are peculiar to the new system.

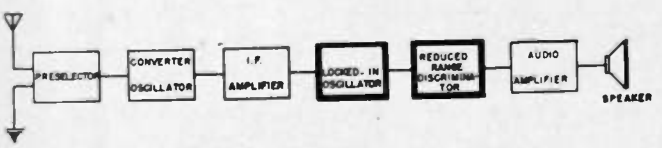


Fig. 1—Block diagram.

Description of the Locked-In Oscillator

The locked-in oscillator circuit diagram is shown in Fig. 2. The tube generally used in this circuit has been an A-5581, an experimental converter tube, which is similar to the 6SA7 but has a higher mutual conductance. The oscillator tuned circuit is connected to the plate of the tube and the feedback coil is connected to

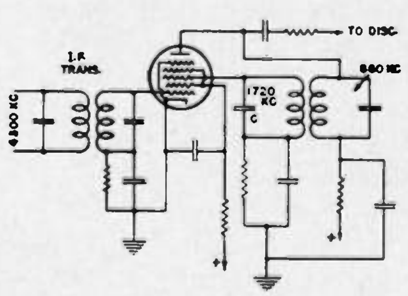


Fig. 2—The locked-in oscillator.

the No. 3 grid. This grid is operated with self-bias. The received signal is applied to the No. 1 grid of the tube through a 4300-kilocycle intermediate-frequency transformer. The No. 1 grid is likewise operated with self-bias.

Description of Discriminator

One type of discriminator that can be used with the locked-in oscillator is shown in Fig. 3. This circuit has a pair of diodes connected with their load resistors in opposition so the discriminator is balanced at the center frequency. One diode has a tuned circuit in series with it and the other has a tuned circuit across it. The discriminator is connected across the tank circuit of the locked-in oscillator through the coupling capacitor shown in the diagram. The audio-frequency output from the discriminator is fed through a de-emphasis network to the audio amplifier.

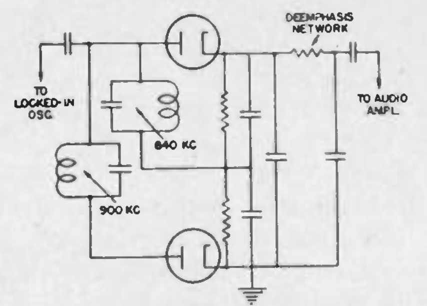


Fig. 3—Discriminator.

Why the Oscillator Locks In with the Received Signal

Theoretical and experimental evidence indicates that the locked-in oscillator circuit operates in accordance with the following theory.

As previously stated, the oscillator is designed to lock in at one fifth the intermediate frequency. With an intermediate frequency of 4300 kilocycles the oscillator tank circuit is tuned to 860 kilocycles. When no signal is being received the tube will function as a normal oscillator. The amplitude of the oscillation in a feedback oscillator is determined by the curvature of the $E_g - I_p$ characteristic and is usually so great that the grid voltage swings well into the curved parts of the tube characteristic during the cycle. This means that a distorted output current is produced in the plate circuit, having component frequencies 2ω, 3ω, 4ω, $\cdots$ where ω is the natural frequency of the tuned plate circuit. These harmonics are applied to the No. 3 grid because of the regenerative coupling. Furthermore, the No. 3 grid operates with self-bias and draws grid current during the positive swings of voltage. The grid-current pulses also contain the harmonics of ω.

Suppose now that the signal voltage of frequency 5ω (4300 kilocycles) is applied to the No. 1 grid. Since the tube is a nonlinear device and operates as a converter, combination frequencies will be produced equal to $\pm 5r\omega \pm s\omega$ where $r, s = 0, 1, 2, 3, \cdots$. Since the plate circuit is tuned to a frequency ω (860 kilocycles), the only frequencies which will be amplified are those of frequency ω; the others will be by-passed effectively. If $r = 1$, then $s = 4$ or 6 will give the frequency ω. This means that either the fourth or the sixth harmonics of the oscillator will beat with the incoming signal, having the frequency 5ω, to give the frequency ω.

This added 860-kilocycle component of the plate current caused by the harmonics of the oscillator beating with the incoming signal is in phase with the 860-kilocycle current in the oscillating plate circuit. The circuit becomes stable in this condition and the injected current will "lock in" the incoming 4300-kilocycle signal with the 860-kilocycle current in the plate circuit. Since the injected current has the same phase and frequency as the normal current, it is merely equivalent to an increased output from the tube.

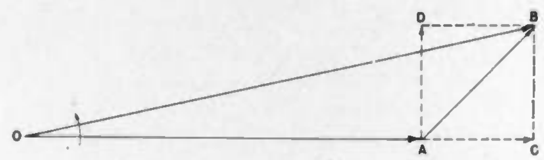


Fig. 4—Vector diagram.

Now suppose that the frequency of the incoming signal is increased somewhat. The effect of the fourth harmonic will be to inject a current of slightly greater frequency than 860 kilocycles into the tank circuit. The sixth harmonic will also cause an injected current of slightly less than 860 kilocycles; this will be considered later. Assume for the moment that the oscillator is *not* locked in. In Fig. 4, OA is a vector rotating 860,000 times per second and represents the normal current in the oscillating tank circuit. Let AB be the injected current of frequency slightly greater than 860 kilocycles, from the fourth harmonic of the oscillator voltage beating with the incoming signal voltage. This vector will rotate slightly faster than 860,000 times per second and thus will have an angular velocity relative to OA equal to the difference of the two angular velocities.

Now consider the instantaneous condition shown in Fig. 4. The injected current AB has a component AC in phase with OA and another component AD, 90 degrees out of phase with respect to OA. Let this resultant current OB be applied to a tuned circuit LC as shown in Fig. 5. Since the LC circuit is tuned to 860 kilocycles, it will be at resonance with respect to the current OC which is also 860 kilocycles and equals i_a+i_b. The quadrature current AD is a leading current at the instant shown by Fig. 4, and the result is the same as though an additional condenser C' is in the circuit. The effect is to *decrease* the natural frequency of the tuned circuit.

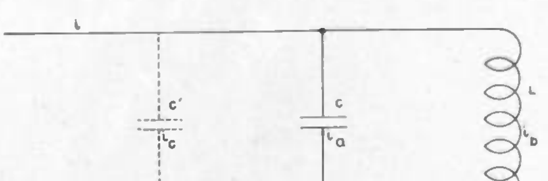


Fig. 5—Effect on circuit.

Now consider the condition at a later instant as shown by Fig. 6. Since the vector AB is rotating with respect to OA it has now rotated to the new position as shown. The injected current AB now has an in-phase component AC as before, but the component AD is now lagging instead of leading. If this current OB is now impressed on the circuit of Fig. 5, the lagging component AD will cancel part of the leading current through C and this will be equivalent to reducing the capacitance C since the circuit is now drawing a smaller leading current. This will raise the resonant frequency of the tuned circuit.

It is now evident that the circuit of Fig. 2 behaves like a reactance tube and swings the frequency of the tuned circuit back and forth. It is easy to see that if the frequency of the incoming signal is approximately five times that of the tuned circuit, a point will be reached when the frequency of the tuned circuit becomes exactly one fifth of the incoming signal frequency. When this happens the oscillator will "lock in" with the incoming signal. This means that the amplitude and phase of the plate current now remain fixed with respect to the incoming signal; vector AB now makes a constant angle CAB with OA.

If the incoming signal is exactly five times the frequency of the tuned-plate circuit, the vector AB will be in phase with OA. As the incoming signal frequency is decreased, the vector AB rotates to some position such as that shown in Fig. 4. A further decrease in frequency will rotate the vector until it is 90 degrees out

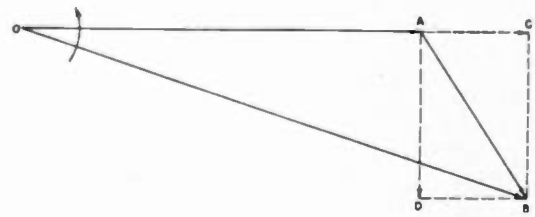


Fig. 6—Vector diagram.

of phase with respect to OA. Since this position gives the maximum amount of quadrature current it corresponds to the maximum amount the oscillator frequency can be pulled over, and thus gives the lower limit of the lock-in range.

If the incoming-signal frequency becomes greater than five times the plate-circuit frequency, the conditions will be similar except that the vector AB will be lagging as shown by Fig. 6 instead of leading. The upper limit of the lock-in range is reached when the injected current lags by 90 degrees. The lagging current tends to reduce the effective capacitance of the circuit and thus raises the frequency.

When the sixth and fourth harmonics are both present simultaneously, it can be shown that the result is a single injected current of variable amplitude and phase. This causes the frequency of the tuned circuit to swing back and forth in accordance with these variations; the process is very similar to that already explained when the fourth harmonic only is present. Usually, the fourth and sixth harmonics will be of unequal amplitude and the effect of the weaker one is to produce relatively small variations in the other.

Lock-In Range Requirements

As previously stated by restricting the lock-in range of the oscillator to frequency variations in the desired channel a material improvement in selectivity can be obtained. On the other hand, it is necessary that the lock-in range be adequate to follow the frequency variations of the received signal and in addition provide for

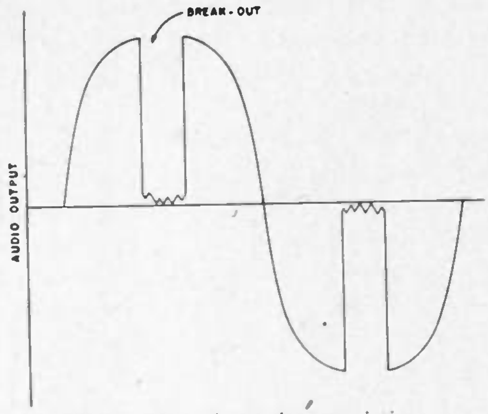


Fig. 7—Breakout characteristic.

receiver mistuning and frequency drift in the transmitter and receiver.

The effect of the fourth and sixth harmonics in controlling the lock-in range of the oscillator has been previously discussed. The amount of fourth and sixth harmonics on the No. 3 grid of the oscillator is limited, and this limits the lock-in range. When the deviation exceeds the lock-in range the oscillator breaks out and starts back toward the center frequency since it is no longer controlled. The oscillator may then suddenly jump to a series of different frequency ratios such as, · · · 36/7, 41/8, 46/9 · · · 5/1, · · · , 44/9, 39/8, 34/7, · · · for short intervals. The lock-in range for each of those ratios is very small, and the oscillator breaks out between them. The result can be a distorted output as shown by Figs. 7 or 8. It is, therefore, necessary to provide adequate lock-in range in order to prevent this distortion.

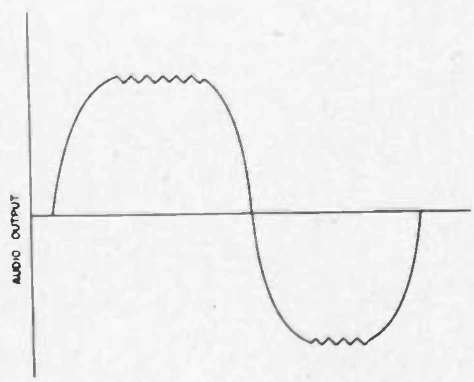


Fig. 8—Breakout characteristic.

Factors Which Determine The Lock-in Range

The lock-in range of the oscillator depends upon several factors which will now be discussed.

Effect of Discriminator

When a discriminator is connected to the oscillator, it changes the impedance relations of the tank circuit and increases the lock-in range. The equivalent input capacitance of the discriminator circuit shown in Fig. 3 decreases rapidly with frequency near the center frequency of the oscillator. Fig. 9 shows how this capacitance falls off near the center frequency f_0. If the oscillator

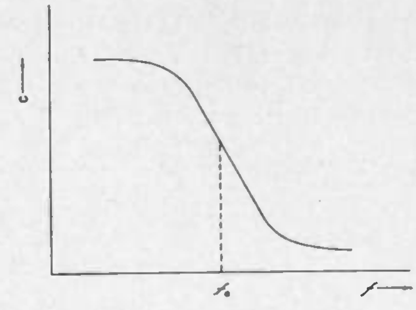


Fig. 9—Input capacitance of discriminator.

tank circuit is to be kept in tune over the operating frequency range, the tank circuit capacitance should decrease with increasing frequency as shown by Fig. 10. The slope of this curve is determined by the L/C ratio of the tank circuit.

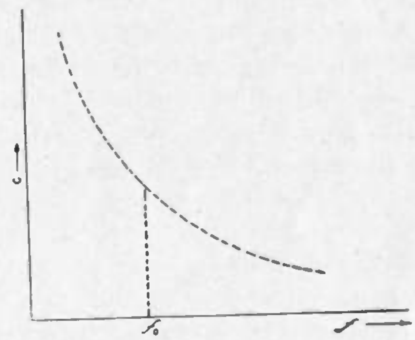


Fig. 10—Oscillator-tuning capacitance.

The discriminator input capacitance characteristic can be designed to provide an apparent capacitance change with frequency nearly to match the requirements for tuning the oscillator.

In Fig. 11 the solid line represents the falling input capacitance of the discriminator and the dashed line is

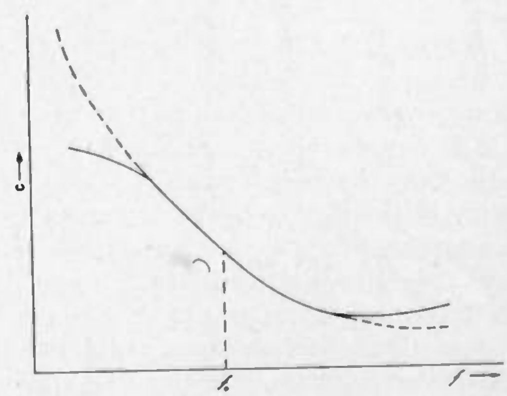


Fig. 11—Matching the discriminator to the oscillator.

the variation of capacitance required to keep the oscillator in tune as the frequency is varied. If the two curves have approximately the same slope at the center frequency f_0, the lock-in range will be greatly increased since only a small amount of reactive current will shift the oscillator frequency a considerable amount.

Effect of Signal Voltage

If the No. 1 grid is operated with self-bias so that the operating bias is approximately equal to the peak amplitude of the applied signal voltage, the lock-in range will be as shown by Fig. 12.

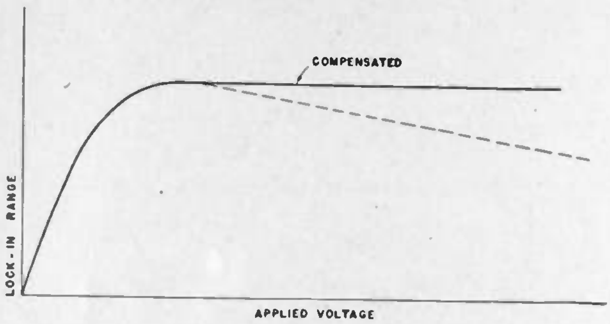


Fig. 12—Effect of signal voltage on lock-in range.

For small appli d voltages the lock-in range increases rapidly from zero with increasing signal voltage until it reaches a maximum, and it then decreases slowly with further increase in voltage as shown by the dashed line.

In practice, the screen and plate resistors can be chosen to correct this falling off of the lock-in range with increased input. This compensation will give the constant lock-in range beyond the knee of the curve as shown by the solid line.

Effect of Tube Constants

The lock in range depends upon the amount of quadrature current that can be developed by the tube. This means that the tube should have a fairly high zero-bias plate current and a fairly high mutual conductance from the No. 1 grid to plate. This assures large pulses of plate current which produce the required reactive current. The experimental A-5581 tube has been found to meet these requirements. This tube is similar to the 6SA7 but provides increased peak current and increased mutual conductance.

Effect of Intermediate-Frequency Selectivity on Lock-In Range

The primary effect of intermediate-frequency selectivity is to attenuate the voltage on the No. 1 grid as the signal frequency moves down the side of the selectivity curve. Naturally the oscillator cannot lock in if the incoming signal voltage becomes too small. This means that the bandwidth of the intermediate-frequency amplifier will affect the lock-in range. Fig. 12 shows the variation of lock-in range with input voltage. The range falls off very rapidly when the applied voltage falls below the knee of the curve. The amplifier should be designed so it is broad enough to assure sufficient voltage to lock in the oscillator at the maximum frequency swings encountered and also to provide for drift and mistuning.

Effect of Oscillator Frequency

The lock-in range is in general inversely proportional to the oscillator tank circuit *C*. An increase in the intermediate frequency will result in an increase in the lock-in range only when *C* is correspondingly reduced.

Effect of Feedback Winding

The lock-in range will increase somewhat with increased mutual inductance from the tank coil to the feedback winding. Fairly tight coupling should be used for increased range.

A method which can be used to increase the lock-in range is to tune the feedback winding to the second harmonic of the oscillator as shown by Fig. 13. Capacitor *C* is chosen to tune the grid circuit to 1720 kilocycles. This builds up the second harmonic, which in turn causes an increase in the fourth and sixth harmonics because of the nonlinearity of the tube. The result is an increase in the lock-in range.

Noise-Reduction Characteristics

It has been previously stated that the locked-in oscillator arrangement can be designed to increase materially the adjacent-channel selectivity of a receiver. This improvement is obtained by restricting the lock-in range of the oscillator so that it will follow only the frequency variations which occur within the desired channel. This restricted lock-in range is of interest also from the standpoint of the noise-reducing properties of the receiver.

In conventional frequency-modulation receivers the discriminator is designed so that the linear portion of its response characteristic is adequate to accommodate the frequency variations of received signals, with due allowance for mistuning both by the user and that resulting from frequency drift of the heterodyne oscillator. The curved portions of the discriminator characteristic which extend beyond the linear region just referred to provide an additional frequency range in which noise components with wide frequency variations are converted into amplitude variations. Fig. 14 shows a typical discriminator characteristic in which *AB* is the linear region within which the frequency variations of received signals are converted into amplitude variations. The sections of the characteristic designated *CA* and *BD* are the portions which are not useful in the reception of desired signals because of the curvature, but which are effective in converting frequency-modulation noise components into amplitude variations. The upper figures, indicating deviation, correspond to the discriminator characteristic in a conventional receiver, while the lower figures

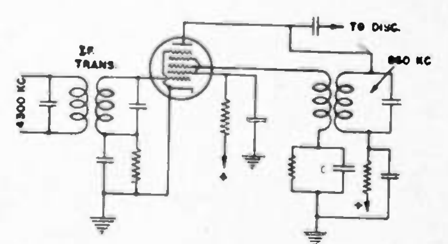


Fig. 13—Tuned-feedback coil.

are the frequency values for the locked-in oscillator discriminator. The restricted frequency range of the oscillator in the locked-in oscillator type of receiver can be used to limit the portion of the discriminator characteristic, which is utilized in converting the frequency variations of both the received signal and noise components into amplitude variations, to the linear region *AB*.

Another characteristic of the locked-in oscillator which may be used to advantage in minimizing the effects of noise is the ability to prevent the oscillator from following the frequency variations corresponding to superaudible noise components. This is accomplished in the oscillator arrangement shown in Fig. 2 by the proper choice of circuit constants.

Modified-Circuit Arrangement

A modification of the frequency-dividing frequency-modulation receiver has been developed by which its ability to select between desired signals and undesired signals or noise is further extended. Fig. 15 is a block diagram of this modification.

The locked-in oscillator used in this arrangement is likewise designed to operate at one fifth of the intermediate frequency. The normal lock-in range of the oscillator, however, is restricted to only 20 to 35 per cent of the frequency-variation range required for received signals. This very restricted lock-in range is extended by means of a reactance-tube arrangement so that the oscillator will follow the maximum frequency variations of received signals. The audio-frequency potential developed at the discriminator-rectifier combination is applied through a phase-correcting network to the reactance tube in the proper phase and magnitude to cause the reactance tube to shift the oscillator resonant frequency so that at any instant its frequency is such that the limited lock-in range will permit it to lock in with

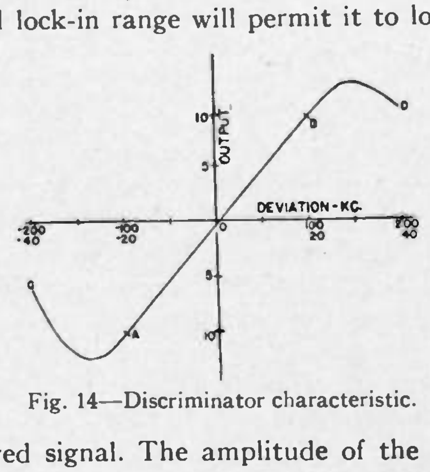


Fig. 14—Discriminator characteristic.

the received signal. The amplitude of the control potential applied to the reactance tube is normally kept slightly below the value which would shift the oscillator to the correct frequency, assuming that the oscillator had no lock-in range. In other words, for 100 per cent modulation the reactance tube shifts the oscillator frequency by slightly less than ±15 kilocycles.

Let us consider the merits of this arrangement in connection with noise impulses and adjacent-channel selectivity. Superaudible frequency-modulation noise components applied to the input circuit of the locked-in oscillator may appear in the oscillator output circuit. The phase-correcting network, however, may be designed so that these components either are not fed back to the reactance tube at all or are not fed back in such phase and amplitude as to permit the oscillator to follow them. In other words, the receiving system is provided

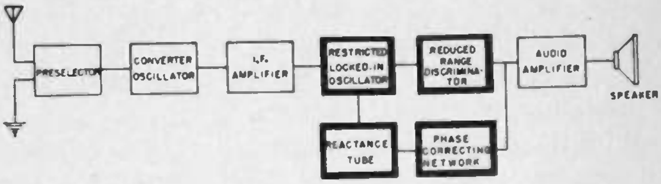


Fig. 15—Modified-circuit arrangement.

with a circuit which is responsive only to small frequency variations and this restricted-response range is moved back and forth at a rate which follows the desired modulation of received signals but is not moved back and forth at a rate which will follow superaudible noise impulses which may be present with the received signals.

The effect of the reactance-tube arrangement on adjacent-channel selectivity is also of interest. This can best be understood by reference to the discriminator-rectifier—voltage-frequency response characteristic shown in Fig. 14. As the output potential of the discriminator-rectifier and hence the potential applied to the reactance tube varies over the useful portion of the discriminator characteristic (the linear portion of the characteristic between the points *A* and *B*) the effect of the reactance tube is to shift the oscillator frequency in the same direction as the frequency changes which give rise to the demodulator potentials. If, on the other hand, we assume that a signal on the adjacent channel could reach the discriminator circuits and produce potentials caused by frequency variations over the side of the discriminator characteristic as indicated by the portion *A–C* of the curve, the phase of the potentials applied to the reactance tube would be such that the effect of the reactance tube on the oscillator would be to reverse the direction of the oscillator-frequency change. That is, the reactance tube cannot shift the oscillator frequency so that it will lock in with the signal on an adjacent channel because the circuit elements are so designed that if the frequency of the oscillator were to change beyond the useful range of the discriminator and towards the adjacent channel, the phase and magnitude of the potential applied to the reactance tube would shift in such a manner that the oscillator frequency would be shifted away from the adjacent channel frequencies.

Experimental Results

As a part of an experimental investigation of the new receiving system, work was carried on with two identical commercial receivers. One was modified by incorporating the locked-in oscillator and reduced-range discriminator, shown in Fig. 16, in place of the two-tube cascade limiter and the discriminator used in the original construction. The other receiver was used for comparative tests in the laboratory and field. This procedure was repeated with two identical laboratory receivers constructed along conventional lines.

It should be noted that the locked-in oscillator circuit shown in Fig. 16 is representative of the receiving system illustrated by the block diagram in Fig. 1. This arrangement was used in preference to the modification illustrated by the block diagram in Fig. 15 because it was less complicated and, therefore, considered more suitable for commercial receivers.

With the arrangement shown in Fig. 16 an intermediate-frequency signal of about 1 volt on the No. 1 grid of the oscillator tube was required to provide the desired lock-in range of approximately ±110 kilocycles. The frequency range in excess of the ±75 kilocycles required for the normal modulation of a received signal is provided to take care of mistuning by the user, frequency drift of the heterodyne oscillator, and overmodulation at the transmitter. The oscillator voltage developed at the discriminator was between 20 and 30 volts. From the foregoing, it is apparent that the receiver should be sufficiently sensitive to produce 1 volt on the No. 1 grid of the oscillator to provide satisfactory reception of a desired signal.

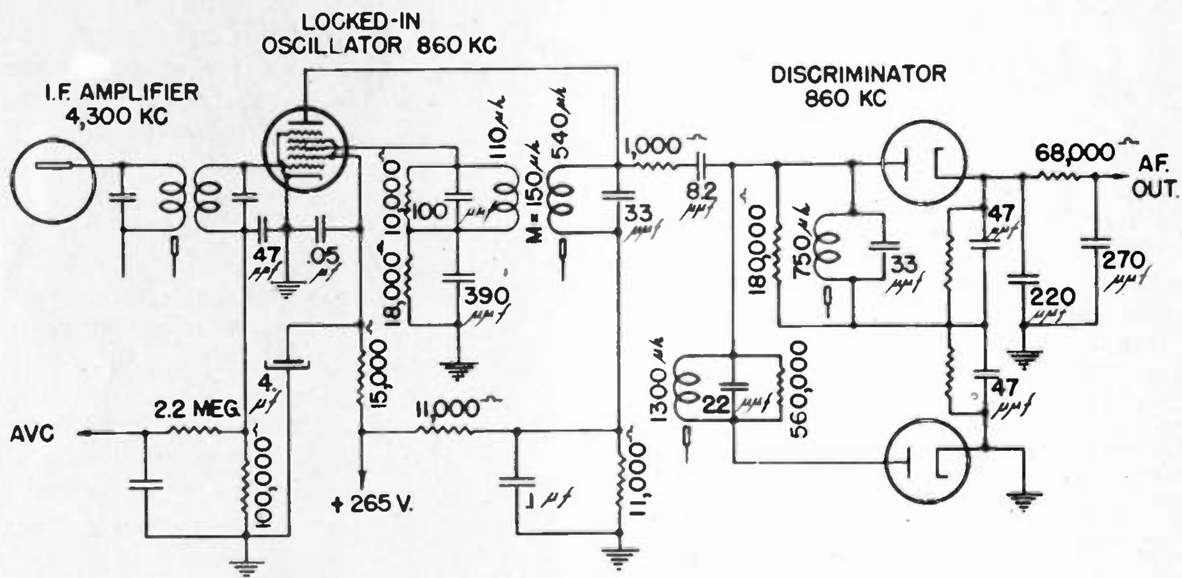


Fig. 16—Locked-in oscillator and discriminator.

Improvement in Selectivity

The results of selectivity measurements, made by the two-signal method, are shown in Fig. 17. In these tests, the receivers were tuned to a desired signal of 100 microvolts, with 400-cycle modulation and a deviation of ±25 kilocycles. An interfering signal, modulated with 1000 cycles, and a deviation of ±25 kilocycles, was adjusted in signal strength and frequency to give an interference output 30 decibels below the 400-cycle output. A considerable improvement in selectivity, especially for the entire adjacent channel, is shown with the receiver employing the frequency-dividing locked-in oscillator system. It should be noted that with an increase in interfering signal, a point of oscillator breakout may always be reached. The level of interfering signal at which breakout occurs is higher than the −30-decibel interference level. The improvement in adjacent-channel selectivity, shown by these curves, is equivalent to the addition of two intermediate-frequency stages in the receiver.

Impulse Noise Interference

Oscilloscopic investigations of the effects of impulse interference with both modulated and unmodulated signals were made with the four receivers. The results indicated a general superiority in noise reduction for the frequency-dividing locked-in oscillator system.

Field Tests

Field tests showed the receivers using the new receiving system to be considerably more selective with respect to adjacent-channel interference than conventional commercial receivers. More distortion was, however, encountered when the locked-in oscillator receivers were tuned so that the signal was received at the edges of the receiver-response characteristic than was obtained with the conventional units. This is due to the oscillator breakout characteristic and the fact that the voltage at the discriminator remains fixed irrespective of the signal applied to the oscillator. In general, it can be stated that an increase in distortion, when tuned to one side of a desired signal, goes hand in hand with increased adjacent-channel selectivity in any type of radio receiver. Some observers felt that this effect assisted in properly tuning the receiver.

Observations with respect to noise reduction substantiated the laboratory measurements which previously have been discussed.

Modified-Circuit Arrangement

An experimental receiver was also constructed incorporating the modified arrangement illustrated by Fig. 15. Although the tests on this receiver were not so extensive as those on the receivers in which the Fig. 16 arrangement was used, they did indicate that the modified circuit possessed superior noise reducing and adjacent-channel selectivity characteristics.

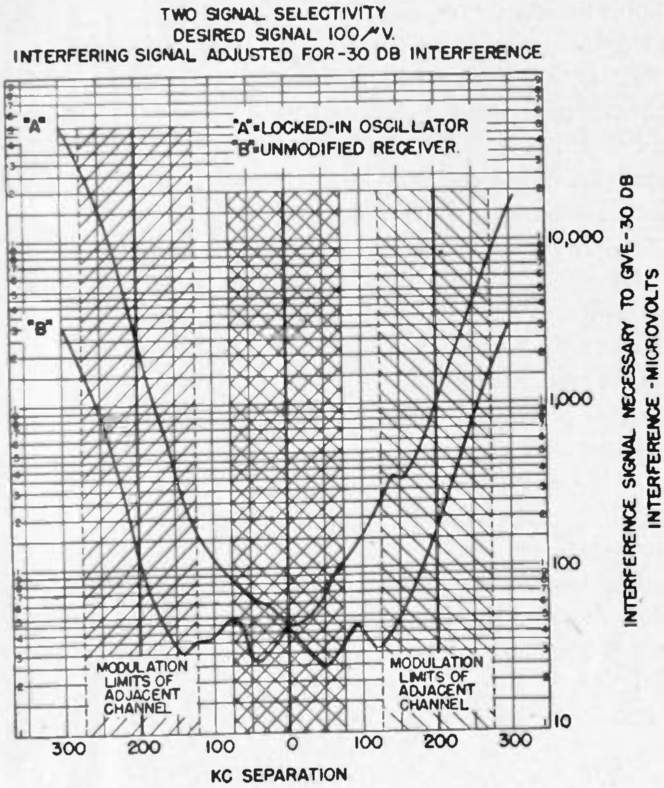


Fig. 17—Selectivity curves.

Conclusions

A novel method of receiving frequency-modulated signals has been investigated both theoretically and experimentally. The investigation indicates that the system has the following advantages:

1. By restricting the lock-in range of the oscillator to follow only the frequency variations which occur within the desired-signal channel, a material improvement in selectivity is obtained.
2. An equivalent voltage step-up is secured at a different and lower frequency than the intermediate-frequency and a corresponding improvement in freedom from over-all feedback is secured.
3. A constant voltage is applied to the discriminator irrespective of the strength of a received signal, and arrangements for minimizing amplitude variations in a received signal are, therefore, not required.
4. The frequency-dividing locked-in oscillator receiving system provides a means for incorporating, in a frequency-modulation receiver, a type of selectivity which can be used to discriminate between the desired-signal modulation and frequency-modulation-noise components.

The following characteristics should also be considered in an evaluation of the system:

1. Adequate receiver gain ahead of the locked-in oscillator must be provided if distortion of the weaker signals (due to the oscillator falling out of step), is to be prevented.
2. When the receiver is tuned through a signal, more noticeable distortion occurs at the edges of the receiver response characteristic than is obtained with a corresponding conventional receiver.

Acknowledgment

The writer wishes to acknowledge the valuable assistance of Messrs. M. S. Corrington, G. L. Grundmann, W. R. Koch, and W. F. Sands during the development of the frequency-dividing locked-in oscillator frequency-modulation receiver.

Electronic Apparatus for Recording and Measuring Electrical Potentials in Nerve and Muscle*

WILLIAM M. ROGERS†, NONMEMBER, I.R.E., AND HORACE O. PARRACK‡, NONMEMBER, I.R.E.

Summary—Electronic apparatus used in studying action potentials is described. It consists of:

1. A variable-frequency stimulator with a volume control which governs the intensity of current used for exciting the nerve or muscle.
2. A trigger circuit synchronizing the sweep of the recording system, a cathode-ray oscilloscope with the stimulator.
3. A recording system, a cathode-ray oscilloscope whose circuit has been altered to permit synchronization with the trigger circuit.
4. A resistance-capacitance-coupled amplifier with one balanced push-pull input stage used as a preamplifier to feed a high-level signal into the differential stage which effectively cancels in-phase signals. This stage is supplied with an input jack permitting its use as the input stage when low-level signals are not encountered. This is followed by three single-ended stages each having an output jack.

A theory of nerve conduction is discussed. The formation of diphasic and monophasic wave forms is described and illustrated. A method for measuring conduction rate is also considered.

ACTIVITY of the nervous system and of muscles is accompanied by changes in electrical potential. These changes are accepted as the electrical signs of activity[1] and are called action potentials. These differences of potential are very small, being of the order of microvolts and millivolts. In a monograph published in 1935, Adrian[2] reviewed the history of electrophysiology. He pointed out that, until recently, advances in this field were limited by lack of sensitive apparatus. With the development of vacuum tubes, apparatus adequate for measuring and recording these minute changes in potential was made available to the physiologist.

Our electronic apparatus for studying bio-electric phenomena consists of

1. A stimulator to excite the nerve or muscle.
2. A trigger circuit to synchronize the horizontal sweep of the cathode-ray oscilloscope with the stimulator.
3. A differential amplifier.
4. A recording system, in our case, a cathode-ray oscilloscope.
5. An extra audio amplifier and recorder with a loudspeaker is not necessary but useful.

* Decimal classification: 621.375.1. Original manuscript received by the Institute, January 3, 1944; revised manuscript received, July 28, 1944. Presented, New York Section, New York, N. Y., October 6, 1943.

† Department of Anatomy, College of Physicians and Surgeons, Columbia University, New York, N. Y.

‡ Formerly, Department of Physiology, Columbia University; now, Captain, Army of the United States.

[1] J. Erlanger and H. Gasser, "Electrical Signs of Nervous Activity," University of Pennsylvania Press, Philadelphia, Pennsylvania, 1937.

[2] E. D. Adrian, "The Mechanism of Nervous Action," University of Pennsylvania Press, Philadelphia, Pennsylvania, 1935.

The stimulator consists of a master timer and a pulse amplifier (Fig. 1).

It is desirable to have a master timer of variable frequency for controlling the stimulus used to activate a nerve or muscle. A neon bulb pulse generator serves this purpose. The frequency of the stimulus is determined by the combination of condensers and resistors used, and varies inversely with capacitance and resistance.

Directly coupled to the timer is a 6J7 tube (T_2) which amplifies the voltage resulting from the condenser discharge. T_2, serving as a buffer amplifier, is followed by one or more independent output units. Each output stage is a pentode (T_3) operated as class C.

A potentiometer (P_1) in the grid circuit of T_3 regulates the amplitude of the stimulating pulse. A bank of coupling condensers in the plate circuit permits selection of wave form.

The ungrounded secondary of an output transformer (Tr_2) delivers the stimulus to the nerve or muscle. Electrodes applied to the nerve or muscle are of silver wire with silver chloride at the points of contact and insulated everywhere else by rubber lacquer.

The Trigger Circuit and the Cathode-Ray Oscilloscope

When this stimulator is used to excite a nerve the horizontal sweep of the cathode-ray oscilloscope must be synchronized with the stimulus applied to the nerve. The same neon resistance-capacitance timing unit is used as a trigger circuit. The condenser voltage, amplified by a 6J7 tube (T_1), whose output is coupled by a transformer to the external synchronization input terminals of the cathode-ray oscilloscope trips the horizontal sweep. To accomplish this in most 3-inch cathode-ray oscilloscope commercial units, certain changes must be made. An RCA stock unit, No. 155 using a 906-(3-inch) cathode-ray tube was modified in the following way in order to synchronize the timing axis oscillator with the external stimulator.[3]

Two potentiometers ($R100$ and $R101$) were added to the bleeder for the power supply of the cathode-ray oscilloscope unit (Fig. 2A). These potentiometers form a trip-sweep adjustment which increases the difference of potential between grid and cathode of the gas-triode oscillator (884). $R100$ in the grid circuit varies the bias in coarse steps. $R101$ in the cathode circuit varies it in fine steps. Proper adjustment prevents the Thyratron from firing until it is tripped by an impulse delivered to the synchronizing transformer. Both potentiometers are returned to zero resistance for normal

[3] This alteration was suggested by Charles Sheer.

operation. The ground connection from the secondary of the synchronizing transformer must be through *R*100.

The resistance in the plate circuit of the horizontal amplifier was increased (Fig. 2B) in order to increase the gain and allow the spot to be displaced from the fluorescent screen of the cathode-ray tube. The original plate circuit is opened by a switch (*S*5) and the current shunted through the higher resistance (*R*102). The switch is closed for normal operation. The above change in the horizontal amplifier reduces the high-frequency response from about 20 to 5 kilocycles, which is adequate for our needs.

The Differential Amplifier

High-gain, low-frequency amplifiers are used for amplifying the action potentials in order that they may be recorded. Various circuit arrangements have been published by different investigators during the past ten years.[4–7] These have considered some or all of the diffi-

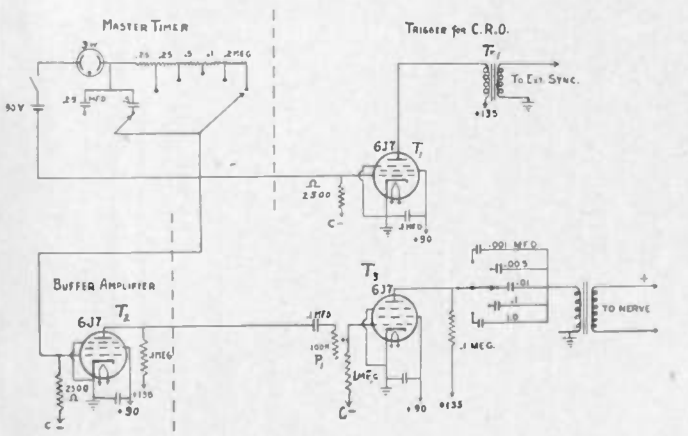


Fig. 1—Circuit diagram of stimulator and trigger circuit for cathode-ray oscilloscope.

culties involved in amplifying action potentials. Elimination of interfering electrical fields has been a primary consideration in every design. Interfering voltages, especially in the 60-cycle fields, which may be of the order of tenths or hundredths of volts between each of the input grids and ground, are the chief offenders. These relatively large alternating voltages are approximately in phase at each input electrode while the small desired signal passing along a nerve or muscle is out of phase. The action potential passing along the nerve is out of phase because it arrives at the first grid electrode before it reaches the second. Thus, we may use the difference in conduction time between the two grid electrodes to give an out-of-phase signal.

Input Stage

Cancellation of the large undesired in-phase signal may be accomplished by the use of a push-pull amplifier or at least a push-pull input stage. Such an amplifier was designed for multiple recording by Matthews[8] and used successfully by him and Adrian.[2] The electrodes placed at different points along the nerve are connected to grids of two matched tubes, 180 degrees out of phase with each other. Their outputs likewise will be out of phase. Interfering voltages reaching the input electrodes will also vary in phase and cancel each other leaving the

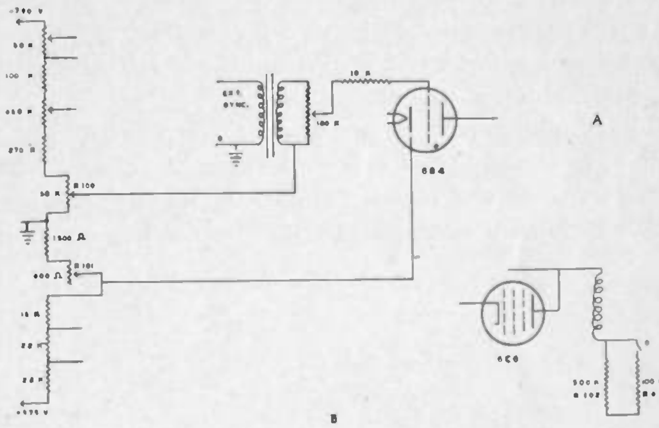


Fig. 2

A—Bleeder for power supply of cathode-ray oscilloscope showing trip-sweep adjustment. For original circuit see RCA No. 155 instruction bulletin (No. I.B.-26417, p. 12).
B—Modified plate circuit of horizontal amplifier.

desired signal from the nerve or muscle. This method of differentiating between the undesired in-phase and the desired out-of-phase signals has led to the designation of these amplifiers as "differential amplifiers." Matthews' design is reasonably inexpensive to build since single-ended stages may be used as second and third stages. Schmitt[7] built another simple differential amplifier requiring only two tubes, two rheostats, and a resistor, which also gave satisfactory results.

More recently Toennies[5] has published data on a differential amplifier. In-phase cancellation is accomplished by employing a high-value cathode resistor which is common to both input tubes (*R*6 in Fig. 3). The high negative grid voltage resulting from this arrangement is compensated for by an opposition voltage or by returning the grids to ground through a positive potential. This input circuit differentiates with marked accuracy a modulation between two ungrounded points against the common modulation of these points. This amplifier may also be followed by single-ended stages. Recently, Traugott[4] in discussing an electroencephalograph design, objected to Toennies' circuit when low noise levels were necessary. Our experience confirms this objection. However, this amplifier does an excellent job of canceling in-phase signals.

Interstage Coupling in Push-Pull Amplifiers

Offner[6] has reviewed several coupling methods for amplifiers when more than one push-pull stage is used.

[4] Paul Traugott, "Electroencephalograph design," *Electronics*, vol. 16, p. 132; August, 1943.

[5] J. F. Toennies, "Differential amplifier," *Rev. Sci. Instr.*, vol. 9, pp. 95–97; March, 1938.

[6] Franklin Offner, "Push-pull resistance coupled amplifiers," *Rev. Sci. Instr.*, vol. 8, pp. 20–21; January, 1937.

[7] Otto H. Schmitt, "A simple differential amplifier," *Rev. Sci. Instr.*, vol. 8, pp. 126–127; April, 1937.

[8] Brian H. C. Matthews, "A special purpose amplifier," *Jour. Physiol.*, vol. 8, pp. 28–29; 1934.

If a dual center tapped push-pull transformer is used to couple the first and second stages, no in-phase signal will result while the out-of-phase signals will be transmitted to the grids of the second stage. However, there are many practical objections to transformer coupling, one of which is the difficulty of obtaining adequate electromagnetic shielding. As a result, a resistance-capacitance coupling is used in most amplifiers for biological research.

One source of internal noise is the vibration of carbon particles when carbon resistors are used for coupling between low-level stages.[9] Wire-wound precision resistors are preferable for this purpose.

The amplifier that we are using consists of two push-pull stages with resistance-capacitance coupling, followed by three single-ended stages, each with an output jack which may be connected to the vertical plates of heater cathode disturbance objected to by Traugott.[4] We have also used successfully a three-stage push-pull amplifier with a volume control between the first and second stages. In studying spontaneous, rhythmic outbursts of action potentials, a loudspeaker is a distinct advantage. Records of electromyocardiograms demonstrated over a portable public address system,[10] illustrate this point.

The above-described apparatus has been put to use in our laboratory for the study of

1. Normal nerve-muscle physiology.
2. Fatigue.
3. Degeneration following nerve injury.[11]
4. Influence of vitamin E deficiency on neuromuscular function.
5. Action of drugs on peripheral nervous system and on muscles.

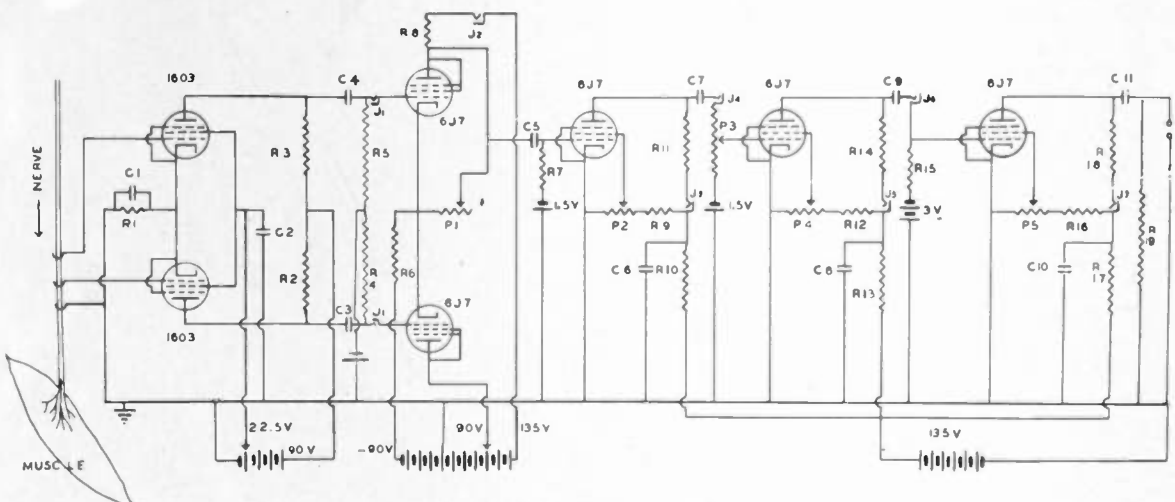


Fig. 3—Circuit diagram of amplifier.

J_1, J_1 are input jacks used when moderately high-level signals are being observed.
J_4 and J_6 are output jacks.
J_2, J_3, J_5, and J_7 are plate-current jacks into which a microammeter may be plugged when adjustments are to be made.
P_1, P_2 and P_4 are 0.5-megohm carbon potentiometers for regulating the screen voltage. A screw adjustment is on the front panel.
P_3 is a 0.5-megohm wire-wound potentiometer controlling the amplification of the last two stages.
R_1 is a 2500-ohm resistor
R_2, R_3, R_4, R_6, R_7, R_{11}, R_{14}, R_{16}, and R_{18} are 0.5 megohm.
R_9, R_{12}, R_{16}, and R_6 are 0.1-megohm resistors.
R_{19} is 1.0 megohm.
R_8 is 0.25 megohm.
R_{10}, R_{13}, and R_{17} are 10,000-ohm resistors.
C_1 is a 50-microfarad condenser.
C_2 is 8 microfarads.
C_3 and C_4 are 0.1 microfarad.
C_5, C_7, C_9, and C_{11} are 1.0 microfarad.
C_6, C_8, and C_{10} are 12 microfarads electrolytic.
The heaters of all tubes are operated on 6-volt storage battery not shown in diagram.

the cathode-ray oscilloscope (Fig. 3). The input stage uses tubes having a low noise factor (type 1603 RCA). The second push-pull stage is the differential stage, a slight modification of the Toennies design. An input jack to the grids of the second stage permits its use as the input stage when less amplification is needed. Input grid leaks are unnecessary since each grid electrode is in contact with two different points on the same nerve, whose resistance is between 1000 and 20,000 ohms. Thus, the nerve itself acts as a grid leak. When low-level signals are to be amplified, the first input stage is used as a differential preamplifier. By feeding a higher-level signal into the Toennies stage, we avoid much of the

Before discussing these uses it is desirable to make a few general statements regarding the nature of the nerve impulse. Although there are different schools of thought on this subject, the most widely accepted view is the Membrane or the Local Circuit Theory. According to this view, a resting nerve is enclosed in a semipermeable polarized membrane. When excited, the local area around the stimulating electrodes is depolarized. Stimulation apparently renders the surface temporarily permeable to the ions on each side of it, thus permitting them to pass through the membrane and neutralize each other. This depolarized area (labeled 0) is negative with

[9] F. E. Terman, "Radio Engineers' Handbook," McGraw-Hill Book Company, New York, N. Y., 1943, p. 477.

[10] Made available through the courtesy of Arthur Washell.
[11] W. M. Rogers and H. O. Parrack, "Anatomico-physiological studies on degenerating peripheral nerves," *Anat. Rec.*, vol. 73, sup. 2, p. 44; April, 1939.

respect to the inactive remainder of the nerve. Thus, a difference in potential exists between the active and resting regions. The depolarized area is rapidly rebuilt by local currents from the inactive area. The region adjacent to the active area becomes depolarized, resulting in a wave of depolarization at approximately zero potential propagated along the nerve fiber (Fig. 4). This self-propagating surface breakdown accompanies the nerve impulse. For a brief time (0.4 to 2 milliseconds) after the passage of the impulse, the repaired area is refractory (Fig. 4). Stimuli falling within this refractory period are ineffective.

Strong support for the "membrane theory" was given by Lillie's[12] experiments. He prepared an iron-wire model which behaved like a nerve. The iron wire when treated with strong nitric acid becomes coated with an oxide film. When this coated wire was placed in a weak acid solution which would cause a gradual disintegration of an untreated wire, no chemical action resulted. The coated wire was said to be in a passive state, comparable to a resting nerve. The coated wire could be "stimulated" to activity by scratching the surface film or by applying an electric current. This initiates an electrochemical reduction which sweeps down the wire. It is

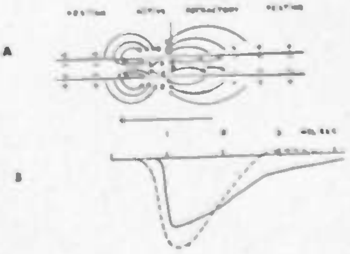


Fig. 4

A—Schematic representation of the membrane or local circuit theory. B—Impedance changes, solid line—action potential, dotted line.

accompanied by an effervescence and the production of a dark-colored lower oxide. By connecting two points along the iron-wire model with a galvanometer the passage of an electric current can be demonstrated. If the acid in which the model is immersed is of the proper concentration a new oxide film reforms in the wake of the reaction. A second stimulation will then cause a repetition of the same phenomenon. The resemblance of the reactions in the iron-wire model to those in a living nerve is very striking. Both are surface phenomena. Recent work of Cole and Curtis[13] also supports the membrane theory. They measured the impedance changes during activity in the giant nerve fibers of the squid. A definite decrease of impedance occurs when the nerve impulse passes any given point. This impedance change occurs suddenly at the moment when the action potential reaches its maximum (Fig. 4B). They consider that the breakdown consists in the sudden and simultaneous change of the membrane electromotive force and conductance which are closely associated properties of a nerve. The current which flows through the membrane reverses in direction at the same time that conductance increases.[14] Impedence changes and potential differences should both be regarded as electrical signs of nerve function.

When alternating-current differences in potential are recorded on a cathode-ray oscilloscope they cause a deflection for each of a pair of grid electrodes in push-pull arrangement. These two deflections are spoken of in electrophysiology as a diphasic action potential which is bidirectional and whose alternate phases cross the zero line (Figs. 5A and 6). A steady current called the current

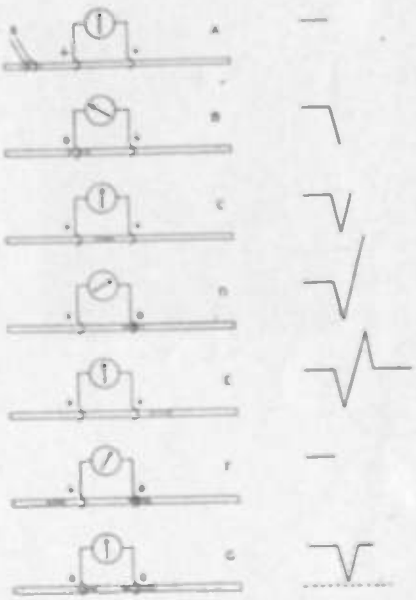


Fig. 5—Simplified diagram of current (left side) and potential (right) changes as recorded on a galvanometer and on a cathode-ray oscilloscope (right) during passage of a nerve impulse. *S* indicates the stimulating electrodes.

of injury may be obtained by crushing the area in contact with the second grid electrode (crosshatched). This may be recorded on the galvonometer but not on the cathode-ray oscilloscope (Fig. 5F). If this preparation is stimulated only one deflection will be recorded on the cathode-ray oscilloscope. This deflection, called a monophasic action potential is unidirectional (does not cross the zero line) and will occur when the impulse (stippled area) reaches the first electrode (Figs. 5G and 7). The maximum deflection approaches the level of zero difference of potential (broken line). Due to crushing of the nerve the impulse never reaches the second electrode.

Conduction Rate

In addition to measuring the amplitude and analyzing the wave form we can study the conduction rate of the nerve impulse. This may be done in several ways, one of which is described below. The first of two pairs of recording electrodes L_1 is in contact with the nerve

[12] R. S. Lillie, "Transmission of physiological influences in protoplasmic systems, especially nerves," *Physiol. Rev.*, vol. 2, pp. 1–33; January, 1922.

[13] K. S. Cole and H. J. Curtis, "Electrical impedance of nerve during activity," *Nature*, vol. 142, pp. 209–210; July, 1938.

[14] H. J. Curtis, "Macleod's Physiology in Modern Medicine," ninth edition, C. V. Mosby Company, St. Louis, Missouri, chapter 7, "The Nerve Impulse."

distal to the stimulating electrodes. At some point distal to the first pair of recording electrodes is a second pair of recording electrodes L_2. The diphasic wave recorded by L_1 is nearer the shock effect than is the wave recorded by L_2 (Fig. 6). A time recording superimposed on the same figure permits us to compute the conduction rate when the distances between S, L_1, and L_2 are known. It has been shown by Erlanger and Gasser[1] that the conduction rate varies with the fiber size (Fig. 7B)[15] and

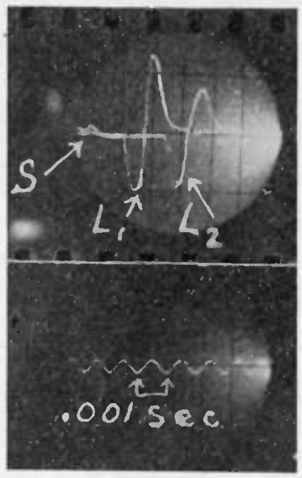


Fig. 6—Diphasic-action potential records.

with the temperature. The conduction rate of the largest fibers (18μ) in the nerves of bullfrogs and other cold-blooded animals is 40 to 42 meters per second (Fig. 6). In mammals and other warm-blooded forms, fibers of the same size have a more rapid rate of conduction (90 to 100 meters per second). Most nerves contain fibers of several diameters, each having a different conduction rate (Fig. 7). The smaller the fiber, the slower its rate.

The threshold necessary to excite the large fibers is less than that required for smaller ones. Fig. 7A is an action-potential record of the largest fibers, designated as α in the sciatic nerve of a bullfrog. The stimulating pulse of 3 volts was sufficient to excite every large fiber. By increasing the voltage (4 to 6 volts) the group of slightly smaller (14μ) fibers were activated. The potential from this group, designated as β, appears as a second, smaller elevation which follows the α spike along the time axis since the smaller fibers have a slower conduction rate (25 meters per second).

One can observe that the amplification is the same for the two records by comparing the alpha spikes. In Fig. 7A the voltage pulse, which reaches both grid leads at

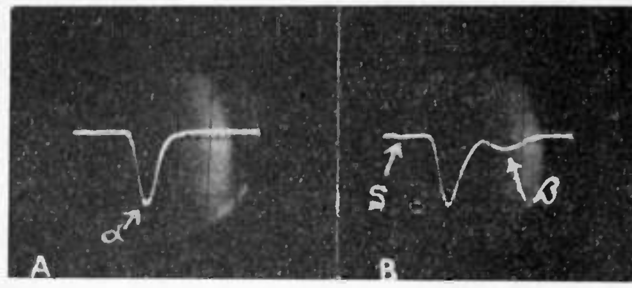


Fig. 7—Monophasic-action potential records.

practically the same time, is entirely canceled. In 7B the increased pulse (S) is barely discernible.

Transmission of Impulse from Nerve to Muscle

Where a motor-nerve fiber terminates on a skeletal muscle fiber, it does so through a specialized ending, called a motor end-plate. Around the nerve terminals is a special substance which transmits the impulse across the nerve-muscle junction and initiates changes in the muscle fiber. When the nerve is stimulated in a normal nerve-muscle preparation, action potentials may be picked up from the nerve by a first set of recording electrodes while the potentials from the muscle may be recorded by a second set. Following prolonged rapid stimulation, the muscle finally fails to contract when the nerve is stimulated, but contracts when the muscle is stimulated directly. Records taken from such a fatigued nerve-muscle preparation show action potentials in the nerve but not in the muscle, indicating that the motor end-plate is the site of fatigue. The same principle has been used in studying the cause of failure in degenerating nerve[16] and in various drug experiments.

[15] All photographic records used were made with a Leica 35-millimeter camera using an $f/2$ lens and either super XX or ultra-speed film.

[16] W. M. Rogers and H. O. Parrack, "Influence of age on functional survival of severed mammalian nerves," *Proc. Amer. Physiol. Soc.*, p. 611P, listed in *Amer. Jour. Physiol.*, vol. 126, no. 3, July, 1939.

Electrical Glass*

EDWIN M. GUYER†, ASSOCIATE, I.R.E.

Summary—**Electrical glass offers the electronics engineer a versatile working medium with useful applications in many types of circuit elements, a dielectric with properties suitable for solving some of his most perplexing problems in electrical insulation.**

The behavior of electrical glass in direct-current and in alternating-current fields is discussed in terms of dielectric properties, considered as functions of field parameters and variables of ambient condition.

Representative values are given in the form of curves which illustrate the wide range of glass properties available for radio engineering service.

Introduction

FROM a practical engineering viewpoint, glass is silica which has been rendered thermoplastic at a convenient working temperature by admixture of borate and alkaline oxide fluxes in combinations and amounts carefully formulated to enhance certain specific properties. The variety of shaping and forming operations thus made possible is unique among modern manufacturing methods.

Electrical glass is glass formulated to meet the special requirements for optimum performance in a wide variety of electrical applications. It serves the radio engineer in four distinctly different ways:

(1) As an insulator to confine the flow of electric current in suitably restricted channels.
(2) As a conductor of electrical energy in the form of alternating potential waves.
(3) As a storage medium for electric energy.
(4) As a vacuum or gastight envelope for numerous electronic devices ranging from miniature radio tubes to giant rectifier bulbs and including sealed housings for such circuit elements as condensers, resistors, and inductors.

But the glass characteristics necessary for successful operation are not limited to electrical properties alone. Thermal, mechanical, and even chemical properties must not be neglected in the business of accurately fitting electrical glass to the service which it is expected to perform.

Thermal Strength

Since the insulation on high-powered, high-voltage systems is sometimes exposed to thermal shock from superficial electrical discharges or flashovers, good arc resistance is an important criterion in the selection of a serviceable material. The remarkably low coefficients of thermal expansion of borosilicate glasses render them highly commendable for this type of service.

Mechanical Strength

In compression, glass is very strong, resisting with impunity crushing forces which would make metals and other structural materials crumble or flow like wax. Since glass is a very hard material, it breaks in tension at lower stresses than it can safely withstand in compression. Thus it is often possible, where great mechanical strength is an important design consideration in an electrical-insulation problem, to process the glass by suitable heat treatment in such a manner that the outside exposed surface is under compression. When this is done properly, the strength may be increased by a factor of three or more.

It is the purpose of this discussion to analyze in terms of characteristic properties those factors which determine the electrical behavior of glass in the difficult insulation problems with which the radio engineer is frequently confronted. In Part I the behavior of glass will be considered in direct-current electrical fields. Part II will deal with glass behavior in alternating-current fields, and in Part III certain special forms of electrical glass will be described. From the wide range of glass properties available, representative values will be given to help in the selection of proper glasses for optimum performance under various conditions of service.

PART I

Behavior of Glass in Direct-Current Electric Fields

In a unidirectional electrical field of constant intensity the behavior of glass as an electrical insulator is determined and controlled by four fundamental electrical properties:

1. Surface electrical resistivity
2. Volume electrical resistivity
3. Specific inductive capacitance or dielectric constant
4. Dielectric strength

Although these properties are to be considered as characteristic of the material, they are definitely modified by ambient conditions. Thus the satisfactory solution of an electrical-insulation problem involving glass, or any other dielectric, requires knowledge of the basic properties considered, not as single valued constants, but as dependent variables in functional relationship with one or more of four independent variables of ambient condition: (1) time, (2) temperature, (3) relative humidity, and (4) atmospheric pressure.

Surface Electrical Resistivity

Surface electrical resistivity is of primary importance in all electrical insulation problems since it affects directly actual performance in service. Due to the adsorption of a moisture film, the surface electrical resistivity of glass, while high in comparison with that of

* Decimal classification R281. Original manuscript received by the Institute, May 29, 1944; revised manuscript received, September 15, 1944.
† Corning Glass Works, Corning, New York.

many other materials, is markedly lower than volume resistivity. Thus chemical durability is an essential requirement in good electrical glass since moisture-film thickness and conductivity both are increased by soluble products of unstable compositions.

Fig. 1 is a plot of representative values showing surface resistivity as a function of relative humidity at 20 degrees centigrade for fused quartz, an ordinary lime glass, and a high-quality borosilicate electrical glass.

The dotted line at the top indicates the order of additional insulation (with respect to surface resistivity)

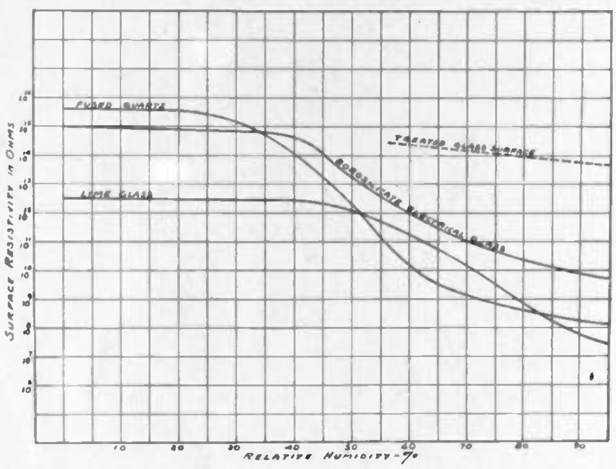


Fig. 1—Surface resistivity as a function of relative humidity for fused quartz, borosilicate electrical glass (Corning no. 774), and lime glass (Corning no. 008).

which can be achieved by means of special surface treatments.

Volume Electrical Resistivity

Volume resistivity when measured in terms of current flowing through unit path per unit of applied voltage, in accordance with Ohm's law for metallic conductors, is markedly affected in glass and other dielectrics by several factors which must be specified to obtain valid results. The current flowing at any instant after application of the voltage is determined not only by the instantaneous voltage and temperature which prevail at the moment of measurement but is a function also of the time which has elapsed since the initial application of voltage, the previous electrical and thermal history of the sample under test,[1] the composition of the glass, and, in some instances, the composition of the electrodes used to contact the glass.[2] This functional relationship between current strength and elapsed time of flow, called dielectric absorption, has been known to students of dielectrics beginning with Benjamin Franklin and studied since that time by an imposing list of famous scientists.[3,4]

[1] E. M. Guyer, "Electrical behavior of glass at room temperature," *Jour. Amer. Ceram. Soc.*, vol. 16, pp. 607–618; December, 1933.

[2] H. R. Kiehl, "Electrical conductivity of glass," *Physics*, vol. 5, pp. 363–369; December, 1934.

[3] John Hopkinson, "Original Papers," vol. 2, Scientific, Cambridge University Press, London, England, 1901, pp. 1–153.

[4] J. B. Whitehead, "Lectures on Dielectric Theory and Insulation," McGraw-Hill Book Company, New York, N. Y., 1927, chapter 2, pp. 18 et. seq.

Dielectric absorption appears as a superposed transient current many times greater in magnitude than the final true electric conduction current by which it is ultimately succeeded. In Fig. 2, a typical charge-and-discharge curve for a lead borosilicate glass plate provided on opposite faces with metal electrodes illustrates several important facts with regard to dielectric absorption in electrical insulation.

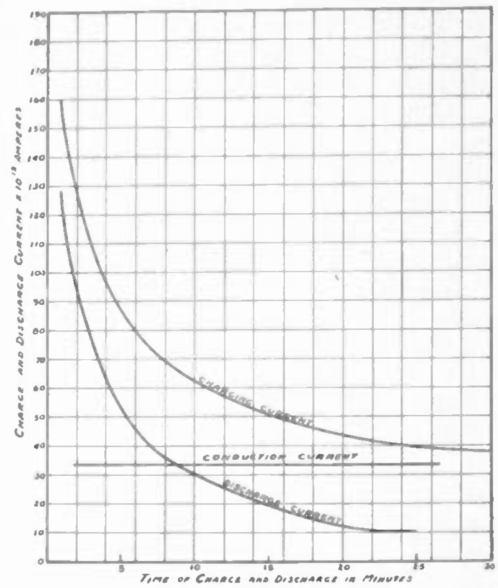


Fig. 2—Charge and discharge curves for a lead borosilicate glass (Corning no. 772).

It will be observed that while a current of 160×10^{-13} ampere flowed through the glass at room temperature (20 degrees centigrade) one minute after application of voltage, the current has dropped to 41.5×10^{-13} ampere after twenty-five minutes of applied voltage. This decrease is current continues for hours depending upon glass composition and temperature, the disappearance of the anomalous current taking place faster at higher temperatures.

From this observation two things are clear. The conventional arbitrary adoption of one minute of elapsed time after the initial application of voltage is unsatisfactory as a standard procedure for glass-resistivity measurements. On the other hand, continued observations until the apparent change in resistivity has decreased to the limits of accuracy of measurement is impracticable where more than a very few samples are to be measured. Fortunately there is a relatively simple solution to this problem since in good electrical glasses the dielectric absorption is reversible. Thus by plotting two curves, one showing the charging current for an interval of time which should be increased (within limits) the greater the desired precision, and the other the discharge current, after voltage removal for a similar interval, it will be found that subtraction of ordinates of the discharge curve from corresponding ordinates of the charge curve will yield values which approximate the true conductivity. This procedure is illustrated in Fig. 2.

Volume resistivity of glass at ordinary room temperatures varies widely with composition from glasses as low as 10^8 ohm centimeters in resistivity to glasses as high as 10^{19} ohm centimeters. The resistivity of a given composition at a fixed temperature may vary by a factor of 3 depending upon the degree of annealing or strain which the glass has received, strained glass having lower resistance than properly annealed glass.

At temperatures well above room temperature, anomalous absorption currents become insignificant in relatively short intervals of time so that these effects are

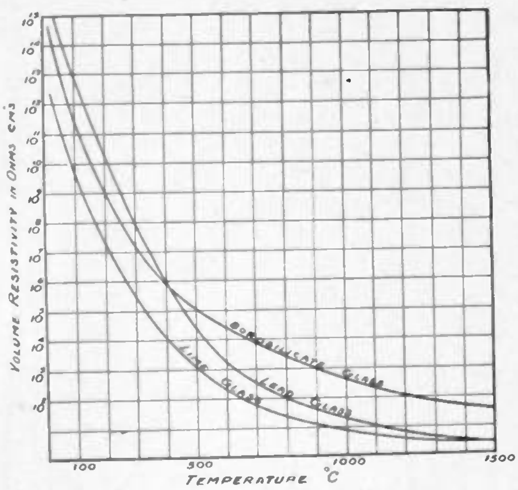


Fig. 3—Volume resistivity as a function of temperature for borosilicate glass (Corning no. 774), lead glass (Corning no. 001), and lime glass (Corning no. 008).

no longer troublesome in volume-resistivity measurements. However, considerable time must be allowed, even at elevated temperatures, for the glass to stabilize, that is, attain a final constant value at the temperature in question.[5]

Fig. 3 illustrates the variation in volume resistivity of three representative types of glass: a lime glass, a lead glass, and a borosilicate electrical glass, over the wide temperature range from ordinary ambient temperatures of 20 to 1500 degrees centigrade. The superiority of the high lead and borosilicate electrical glasses over lime glass is evident.

Specific Inductive Capacitance or Dielectric Constant

Dielectric constant, defined as the ratio of the capacity of a given electrode configuration including a specific dielectric to the capacitance of this same electrode system in vacuum (without the dielectric), varies with glass composition from a little less than 4 to values of 16 and over.

In direct-current fields at ordinary room temperatures dielectric absorption affects dielectric constant measurements giving values which vary with the time of applied potential or charging time. Curie and Compan[6] observed increases in dielectric constant of 43 per cent from 7.89 to 11.25 for potash-lime glass for variations in time of charge from 0.05 second to 10 seconds. At very low temperatures (−75 degrees centigrade) dielectric constant has been found to be independent of time of charge. At ordinary room temperatures and above, dielectric constant increases markedly with temperature at rates which vary with glass composition, being least in high silica and borosilicate electrical glasses and greater in lime glasses containing substantial amounts of alkali.

In addition to the obvious effect of high-dielectric-constant glasses on the capacitance of the circuit elements into which they enter, it is to be noted that their high-dielectric strengths may be of even greater significance in energy-storage systems. Since the energy which can be stored in a condenser varies as the first power of the dielectric constant and the second power of the voltage, a glass with twice the dielectric strength is as effective as one with four times the dielectric constant.

Dielectric Strength

While the surface and volume resistivities together with the dielectric constant each affect the behavior of glass in direct-current fields of arbitrary intensity, the important matter of how great the voltage can safely be allowed to grow without danger of breakdown is determined by the fourth property, the dielectric strength. Of all four properties, dielectric strength is the most difficult of measurement and the least certain of interpretation. A good deal has been written in the literature on the physical mechanisms responsible for the complex behavior but much remains to be established before there can be satisfactory agreement between the different theories so far advanced. Meanwhile, the engineer must content himself with testing dielectrics for electrical breakdown under circumstances as nearly identical with actual service conditions as possible, proceeding cautiously when definite departures from these test conditions are unavoidable.

The voltage gradient, across the dielectric, at which electrical failure takes place varies with (1) the characteristics of the ambient testing medium, (2) the nature and manner of application of the impressed electric field, and (3) the composition, form, and condition of the glass sample under test.

Failure to specify the variables controlling each of these separate factors accounts for the difficulty in correlating much of the recorded data on dieletric strength.

Although a detailed analysis is beyond the scope of this discussion, an excellent critical examination of this complex problem has been given by Littleton and Morey[7] from which certain observations are here summarized to help in the proper selection and treatment of glass dielectrics for high-voltage service.

Because the dielectric strength of glass is much

[5] J. T. Littleton and W. L. Wetmore, "The electrical conductivity of glass in the annealing zone as a function of time and temperature," *Jour. Amer. Ceram. Soc.*, vol. 19, pp. 243–245; September, 1936.

[6] Curie and Compan, *Comptes Rendus*, vol. 134, p. 1295; 1902.

[7] J. T. Littleton and G. W. Morey, "The Electrical Properties of Glass," John Wiley and Sons, Inc., New York, N. Y., 1933, chapter V, "Dielectric Strength."

greater than most other substances including the air and conventional insulating liquids such as oil, used for convenience to avoid surface flashover, the results obtained in such tests are characteristic of the weaker medium in which the glass is tested rather than the glass itself.

What is actually measured is not so much dielectric strength as corona resistance or the ability to withstand bombardment with the ions from the localized discharges occurring in the weaker gaseous or liquid medium. Different glasses and even nonvitreous products with widely different dielectric strengths will thus appear to have the same breakdown voltage, namely, that of the oil in which they are tested, and in different oils, will show as many different apparent dielectric strengths.

The only remedy seems to be the application of special techniques of measurement which avoid the localized discharges at points of nonuniform electrical stress concentration in the medium about the test electrodes.

In considering briefly the effect of composition, form, and condition of the glass on dielectric strength, it should be noted that it was not until procedures were developed which eliminated edge effect that results were available which were sufficiently consistent to separate the controlling factors.

Glass temperature determines not only the magnitude of the breakdown voltage but also the type of dielectric failure. At low temperatures and with thin sections, glass fails by purely disruptive breakdown, resulting directly from electrical overstress of the dielectric without evidence of internal heating.

At higher temperatures the breakdown is largely of the thermal type. Dielectric heating becomes cumulative as losses raise the temperature which, in turn, increases the dielectric loss. The upper curve of Fig. 4 shows the variation of the dielectric strength of lime glass with temperature in the thermal breakdown region. Moon and Norcross[8] working with samples of 200 micron thickness found the following relative values of breakdown voltage in the disruptive region and thermal breakdown region at 300 degrees centigrade for the four types of glass illustrated.

TABLE I

Kind of Glass	Disruptive kilovolts per centimeter	Thermal kilovolts per centimeter
Fused-quartz glass	5000	560
Borosilicate glass	4800	200
Lead glass	3100	102
Lime glass	4500	32

As expected, glass compositions which show highest electrical resistivity at elevated temperatures have, in general, highest dielectric strength for thermal breakdown at the elevated temperatures. This does not imply correlation, however, between dielectric strength and electrical resistivity at low temperatures.

[8] P. H. Moon and A. S. Norcross, "Three regions of dielectric breakdown," *Elec. Eng.*, vol. 49, p. 762; April, 1930.

Disruptive breakdown voltage increases directly with thickness. Thermal breakdown gradient, on the contrary decreases for thicker sections due largely to cumulative overheating. This will be discussed further in considering glass behavior in high-frequency fields.

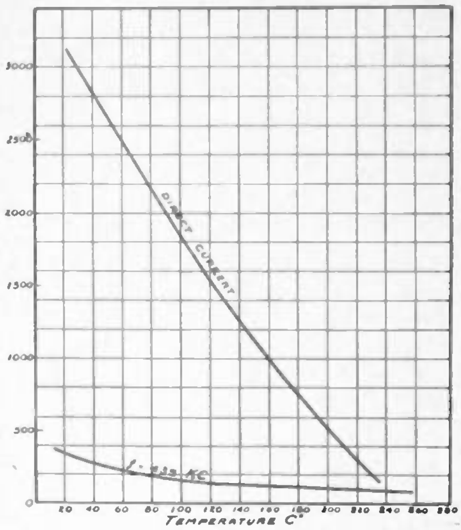


Fig. 4—Breakdown voltage as a function of temperature for direct current and for 435-kilocycle alternating current.

PART II

Behavior of Glass in Periodic Electric Fields

The behavior of glass (and all other dielectrics) in fields which vary periodically in intensity and direction is dominated by the phenomena of dielectric loss. Anomalous absorption currents are predominant over conduction currents since the time of current flow between reversals of the field is, in practice, much shorter than the time duration of the transient absorption currents. Dielectric absorption, plus conduction, transforms electrical energy into heat since both represent components of current flow in phase with the alternating electric field, in contrast to the 90-degree phase relation between the current and voltage vectors of a hypothetical wattless condenser. Inasmuch as all properties, electrical, mechanical, and chemical, vary with temperature, it is obvious that the primary factor which determines the rate of heat generation in the cyclically polarized dielectric will control the consequent variations in all of these properties. In operation at low voltages and power levels, low-loss insulation is desirable to improve circuit performance. At high voltages and power levels, dielectric losses must be minimized not only to improve circuit performance but also to avoid destruction of the insulation itself by cumulative heating. Thus it is of primary concern in the selection of high-frequency insulation to know how much of the field energy will be wasted in heating up the dielectric and how this will affect the life and performance of the insulated system.

Dielectric Loss

Energy expended by the field in heating up the insulation is represented vectorially by the dielectric power factor or loss angle which is the complement of the phase angle between the impressed sinusoidal voltage and resultant dielectric current. More specifically it can be represented by the loss factor which is the product of the tangent of the loss angle and the dielectric constant.[9]

Power loss in watts per unit volume of dielectric, per cycle, per unit potential gradient, may be expressed conveniently in terms of a numerical unit constant, and the loss factor LF. Thus since the power loss varies directly with frequency of the applied voltage and the square of the potential gradient, power loss in watts per unit volume may be calculated at any specified frequency and voltage by the equation:

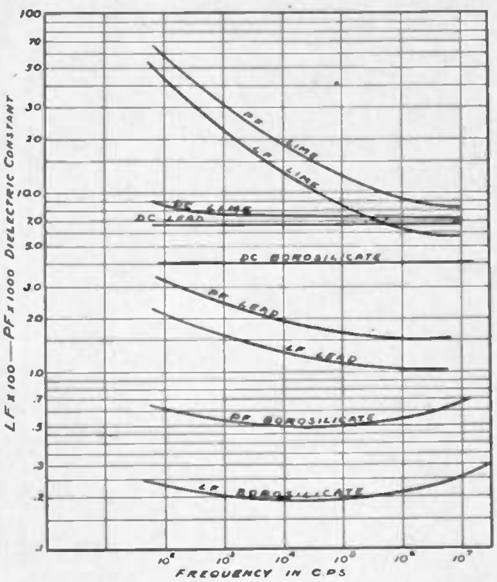


Fig. 5—Variation of power factor (PF), loss factor (LF), and dielectric constant (DC) with frequency for borosilicate glass (Corning no. 707), lead glass (Corning no. 001), and lime glass (Corning no. 008).

$$P/V = 0.555LF \cdot f \cdot E_0^2 \qquad (1)$$

where f is frequency in megacycles, E_0 is potential gradient in kilovolts per centimeter, and LF is the product of the dielectric constant (ratio without dimensions) and tangent of the loss angle.

Fig. 5 shows the variation of the loss factor with frequency over the wide range from 60 cycles to 10 megacycles per second, for three representative glasses, a high-quality borosilicate and a lead glass suitable for radio service, and, for purposes of comparison, an ordinary lime glass. The marked superiority of the radio glasses is evident.

While in all cases the loss factor is relatively much higher at the lower frequencies, the need for the higher-quality glasses is nevertheless more urgent at the high-frequency end of the spectrum since it is the actual loss in watts per unit volume of dielectric which determines radio field performance. An equally important consideration is the variation of the loss factor with temperature since dielectric heating increases dielectric losses cumulatively. Fig. 6 (right) shows the variation with temperature of loss factor, for a high silica and a low alkali borosilicate electrical glass in comparison with fused quartz.

While in most high-frequency insulation problems the loss factor is the most important consideration, there are some electrical-glass applications, such as capacitor design, where knowledge of the behavior of each component, the dielectric constant, and the power factor considered separately, is of interest.

Power Factor

Power factor varies with glass composition, the frequency of the applied field, and the temperature of the glass. Fig. 5 shows this variation of power factor with frequency for a low-loss borosilicate glass, a lead glass, and for an ordinary soda-lime glass. Fig. 6 (left) shows the behavior of the power factor with respect to temperature.

Expanded plots for both dielectric constant and power factor for several representative glasses measured in round-robin tests in several different laboratories, over a wide range of frequencies will be found in a paper by Richards.[10]

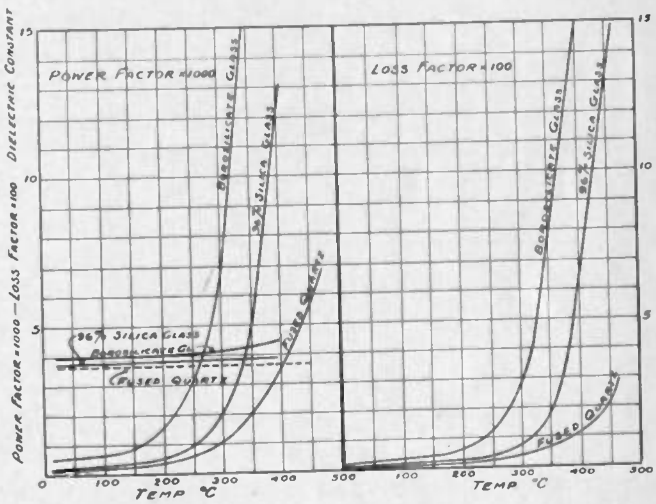


Fig. 6—Power factor and loss factor as functions of temperature for fused quartz, borosilicate glass (Corning no. 707), and 96 per cent silica glass (Corning no. 790).

Dielectric Constant in Alternating-Current Fields

The dielectric constant of most glasses decreases as the frequency of the applied field increases, the variation being large for high-loss glasses and relatively much less for low-loss electrical glass. Rising temperature increases dielectric constant but the percentage increase is less at high frequencies than at low.

This behavior is illustrated in Figs. 5 and 6.

Surface and Volume Resistivity

Surface and volume resistivity are of considerably less importance in alternating-current fields than in direct-current fields because of the relatively much

[9] E. T. Hoch, "Power losses in insulating materials," *Bell Sys. Tech. Jour.*, vol. 1, pp. 110–117; November, 1922.

[10] P. A. Richards, "Report on round-robin tests of power factor and dielectric constant for glass," *Amer. Soc. Test. Materials Proceedings*, 44th Annual Meeting, vol. 41, pp. 1183–1197; June, 1941.

greater magnitudes of the dielectric-displacement currents in comparison with the conduction currents. Unless ambient temperature and humidity are very high, only a small part of the total dielectric loss in high-frequency fields can be accounted for by electrical conductivity.

Yager and Morgan[11] have shown the part played by surface and volume conductivity in determining glass behavior in high frequency fields.

The family of curves in Fig. 7 (from their paper) shows the variation in surface conductivity of a borosilicate electrical glass with relative humidity at different frequencies and temperatures. Surface conductivity is seen to increase with frequency and to a greater extent at higher humidities than at lower. While surface conductivity increases with ambient temperature this

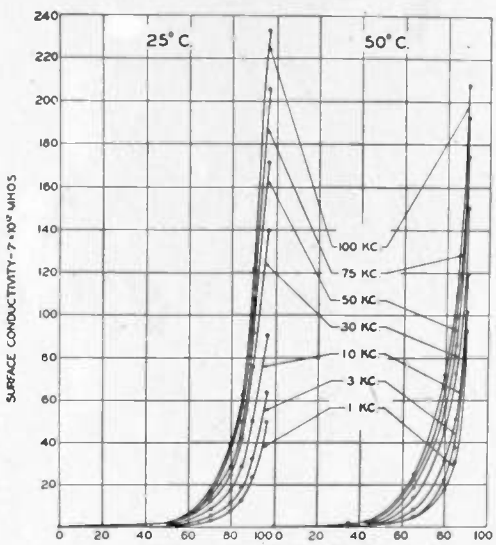


Fig. 7—Surface conductivity as a function of relative humidity at different frequencies.

factor of increase is relatively small in comparison with the changes due to variations in either the frequency or the relative humidity.

Dielectric Strength in Alternating-Current Fields

At low temperatures and frequencies, under conditions such that edge effect is properly eliminated and breakdown is disruptive in character, most investigators have found no difference in the dielectric strength of glass whether determined by impulse test, in direct-current fields, or in alternating-current fields, provided peak voltage is used as the basis of comparison. Because of the phenomena of dielectric loss, however, it is apparent that thermal breakdown will play an increasingly important role in glass behavior in alternating-current fields and that this fact will become more pronounced at the higher frequencies. Thus dielectric failure in practice is largely determined by the thermal parameters of the glass system and ambient medium in addition to the electrical characteristics of the glass and the dielectric loss factor becomes an essential part of high-frequency dielectric strength.

This is illustrated in Fig. 4 where the breakdown voltage is seen to decrease at 20 degrees centigrade from over 3000 kilovolts per centimeter for direct current to less than 400 kilovolts per centimeter at 435 kilocycles.

The relatively much smaller difference between direct-current and high-frequency breakdown at higher glass temperatures is also apparent. Thus for the lime glass in question there is no difference between high and low frequency breakdown at temperatures above 240 degrees centigrade.

A comprehensive summary of alternating-current dielectric-strength data on glass collected from many different sources and presented in convenient graphical form will be found in a recent paper by Shand.[12]

PART III

Special Forms of Electrical Glass

Certain special forms of electrical glass which are rapidly finding useful applications in the electrical insulation field are the product of new processes involving radical departures from established methods of glass fabrication are (1) fiber glass electrical insulation, (2) multiform electrical glass, (3) VYCOR brand 96 per cent silica electrical glass, and (4) new combinations in glass-metal seals.

Fiber-Glass Electrical Insulation

Fiber glass, as applied in electrical-insulation tapes, braided sleeving, electrical cloth, cordage, laminated products, and mica combinations, owes its success to the extraordinary tensile strength of fine glass fibers, their resistance to temperature, and their desirable electrical properties. Motors, generators, transformers, reactors, relays, meters, and all manner of electromagnetic equipment have profited by the reduction of winding space and higher safe operating temperatures which fiber-glass insulation provides. Even after treatment with suitable impregnating varnishes the marked superiority of these inorganic fibers is still dominant over comparable products similarly treated, as illustrated in Figs. 8 and 9.

Multiform Electrical Glass

In the past the production of electrical glass parts by conventional glass making methods—blowing, pressing, and drawing—have had definite limitations. Shapes have had to be relatively simple and special design features such as holes, grooves, or threads have been major problems for the glassmaker. It has also been difficult with the conventional methods to hold close tolerances in the dimensions of glass parts. The results of these limitations in shape, design, and accuracy has

[11] W. A. Yager and S. O. Morgan, "Surface leakage of pyrex glass," *Jour. Phys. Chem.*, vol. 35, pp. 2026–2042; 1931.

[12] E. B. Shand, "The dielectric strength of glass—An engineering viewpoint," *Elec. Eng.*, vol. 60, pp. 41–91; March, 1941.

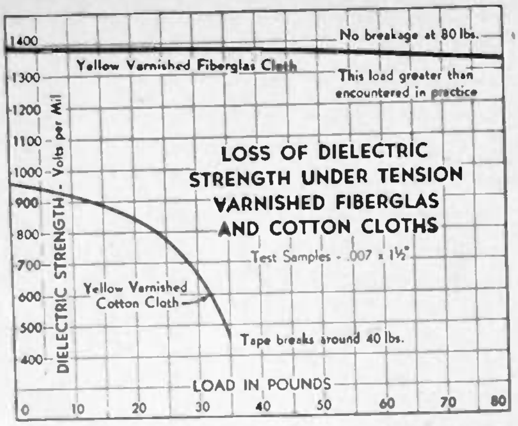


Fig. 8—Loss of dielectric strength under tension varnished fiberglas and cotton cloths.

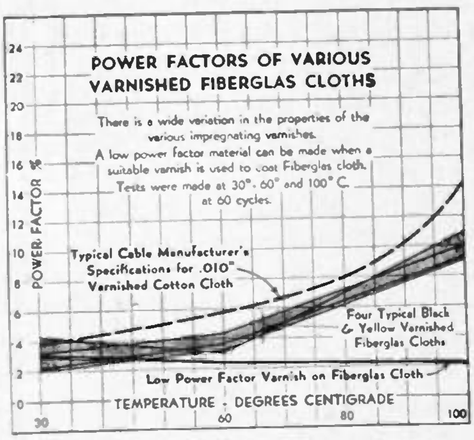


Fig. 9—Power factors of various varnished fiberglas cloths.

been to preclude the use of glass in many applications where the qualities of the material have been suitable.

A wide range of new applications of electrical glass has been made available by the recent development at Corning of the Multiform process of glass making, in which successful production of intricate insulating parts of unusual shape and with close dimensional tolerances has been achieved. A number of glass compositions having widely different characteristics are available and have found applications in products ranging from small insulating beads, running several thousand to the pound to large insulators and bushings weighing 25 pounds or more.

General dimensional tolerances are: large or heavy pieces, intricate shapes, hollow cylindrical sections—±2.0 per cent or 0.010 inch; flat plates, solid rods, disks, beads, bushings—±1.0 per cent or 0.005 inch, excepting thickness which should be ±4.0 per cent or 0.01 inch. This glassware can be ground and polished to closer tolerances when necessary.

Properties of glasses made by the Multiform process are given in the following table in comparison with glass No. 774 made by conventional processes.

The range of practical design of glass parts for all manner of electrical-circuit elements from coil forms and capacitors to fittings and internal insulating structures for electronic tubes is enormously extended by the development of the Multiform process.

TABLE II

Glasses Made by Multiform Processes Compared to No. 774 Glass Made by Conventional Processes

Process Glass No.	Unit	Multiform 790	Multiform 7761	Multiform 707	Conventional 774
Linear coefficient expansion (0–300 degrees centigrade)	per degrees centigrade $\times 10^{-7}$	7.5	33	32	33
Maximum service temperature	degrees centigrade	800	460	450	510
Log R at 250 degrees centigrade	ohm centimeters	9.8	12.0	11.2	8.1
Log R at 350 degrees centigrade	ohm centimeters	8.1	10.0	9.1	6.7
Power factor at 1 megacycle 20 degrees centigrade	per cent	0.10 to 0.18	0.11	.08	0.42
Dielectric constant at 20 degrees centigrade 1 megacycle		4.0	4.0	4.0	4.7

VYCOR Brand 96 Per Cent Silica Electrical Glass No. 790

This glass is approximately 96 per cent silica and compares favorably with fused quartz in thermal properties and performance. For operations at very high temperatures and insulating problems where high arc resistance is desirable, it is a marked advance over all other glasses with the exception of pure fused silica. Because of newly developed methods of manufacture, glass No. 790 can be fabricated and formed as an easily workable glass of relatively low melting point after which a special chemical process removes practically all constituents except silica. A high-temperature firing subsequently consolidates this porous shell into the finished ware. Its properties are compared with other materials as shown in Table III.

TABLE III

Characteristics of Glass No. 790 Compared to Other Materials

Physical Property	96 Per Cent Silica Glass No. 790	Pyrex Brand Glass No. 774	Fused Silica
Softening point, degrees centigrade	1500	819	*1667
Annealing point, degrees centigrade	910	553	*1140
Strain point, degrees centigrade	820	510	*1070
Maximum operating temperature, degrees centigrade	900	510	1000
Linear coefficient expansion per degree centigrade (From 0 to 300 degrees centigrade)	7.5×10^{-7}	33×10^{-7}	$*5.5\times 10^{-7}$
Specific gravity	2.18	2.23	*2.20
Index of refraction	1.458	1.474	*1.458

* General Electric Company.

New Combinations in Glass-Metal Seals

As the large family of present-day electronic tubes continues its rapid growth, both in number and variety, the problem of sealing electrically conducting vacuum-tight leads into the insulating glass envelopes of vacuum and low-pressure discharge devices confronts the tube engineer with ever greater frequency. Rising power levels demand larger conductors in these seals, as do the newer circuit elements such as vacuum capacitors, which must carry many amperes of circulating current in tuned tank circuits. Higher plate voltages on power tubes and high-voltage vacuum switches, relays, and circuit breakers put greater dielectric stress on seals and envelopes alike. Thus glass-to-metal seals, while old to the glass art, are of constantly increasing importance to the radio engineer.

The basic requirements which glass and metal properties must meet for satisfactory seals in modern electrical service are:[13–16]

(1) There must be strong adhesion at the glass-metal interface. This generally involves solution by the glass of a tough adherent oxide coating formed by suitable treatment of the metal.

(2) The relative expansion coefficients must be so related that residual stresses are less than the tensile strength of the glass. In this connection, it is to be noted that the necessity of expansion matching applies over the temperature range up to the softening point of the glass. Even with properly matched expansion coefficients, glass-to-metal seals will not be free of strain unless properly heat-treated after the sealing operation is completed.[17]

Seals to specially prepared edges of ductile metals[18] preceded more recent matched expansion glass-metal combinations and are still used in many applications.

(3) The metal must be sufficiently conducting to carry the currents required in service without overheating and to permit electrical welding or other desired metal bonding operations with connected circuit elements or associated structural parts.

(4) The glass must have sufficient stability, chemical durability, electrical resistivity, and low dielectric loss at operating temperatures to avoid electrical failure either by conduction augmented by electrolysis or by thermal failure due to cumulative high-frequency heating.

Credit for fulfilling these exacting and often mutually antagonistic requirements belongs jointly to the glass technologist and metallurgist, whose co-operative research has provided the tube engineer with a wide variety of useful combinations, ranging from glasses to match cold-rolled steel at 137×10^{-7} centimeter per degree centigrade, per unit length to tungsten at 45×10^{-7}. Details of proper procedure for making glass-to-metal seals have been published.[13–20]

Still another form of hermetic sealing of glass to metals has been developed which permits the attachment of metal parts or fittings to glass electrical bushings, by soldering to metallized glass.[21] This process is finding current application to provide hermetic seals for leads and terminals on metal cases of transformers and condensers, permanently attached windings of fixed characteristics for high-frequency coils, glass condenser electrodes, and conducting screens for high-voltage or high-frequency electric fields.

Conclusions

The data on glass properties brought out in the preceding discussion may be summarized as follows:

(1) Surface resistivity varies with composition, temperature, and relative humidity from 10^{16} to 10^7 ohms. With alternating-current potentials surface resistivity decreases as frequency increases.

(2) Volume resistivity at room temperature varies from 10^{19} to 10^8 ohm centimeters with glass composition. As temperature increases to the melting point all glasses become electrically conducting molten electrolytes with resistivities of a few ohms or less.

(3) Dielectric constant in direct-current fields varies with time of charge. In alternating-current fields the dielectric constant of glass varies from less than 4 to over 16.

(4) Power factor of glass varies from 0.05 per cent or less for good borosilicate electrical glass to several per cent for alkali glasses.

(5) Loss factor varies from 0.0021 for low-loss electrical borosilicates at radio frequencies to over 50 for alkali-lime glass at 60 cycles.

(6) Dielectric strength is very high when edge effect and breakdown of the ambient medium are eliminated by proper design.

(7) Special forms of electrical glass of recent development which are finding wide application in insulation problems include (1) fiber-glass tapes, braided sleeving, cordage, laminated products, electrical cloth and mica combinations, (2) multiform glass parts of intricate shape and accurate dimensions, (3) VYCOR Brand 96 per cent silica glass products in clear form and multiform, and (4) a wide variety of glass-to-metal seal combinations including metallized glass for soldered bushing and terminal connections, and permanently fixed coil windings and electrodes.

[13] H. Scott, "Recent development in metal sealing into glass," *Jour. Frank. Inst.*, vol. 220, pp. 733–753; December, 1935.

[14] A. W. Hull and E. E. Burger, "Glass-to-metal seals," *Physics*, vol. 5, pp. 384–411; December, 1934.

[15] W. E. Kingston, "Low expansion alloys for glass-to-metal seals," *Trans. Amer. Soc. Metals*, vol. 30, pp. 47–67; March, 1942.

[16] A. W. Hull, E. E. Burger, and L. Navias, "Glass-to-metal seals II," *Jour. Appl. Phys.*, vol. 12, pp. 698–707; September, 1941.

[17] J. T. Littleton, "The effect of temperature treatment on glass-to-metal seals," *Jour. Amer. Ceramic Soc.*, vol. 18, pp. 239–245; August, 1935.

[18] W. G. Houskeeper, "The art of sealing base metals to glass," *Trans. A.I.E.E.* (*Elec. Eng.*, vol. 42, June, 1923), vol. 42, pp. 870–877; June, 1923.

[19] J. Strong and Collaborators, "Procedures in Experimental Physics," Prentice-Hall, Inc., New York, N. Y., 1938, chapter 1.

[20] Corning Glass Works Publication, "Laboratory Glass Blowing with Pyrex Brand Glass," pp. 17–18; 1938.

[21] D. E. Newton, "Methods of hermetic sealing," Part I, *FM Radio Electronics*, vol. 3, pp. 22–25; June, 1943; Part II, vol. 3, pp. 14–16; July, 1943.

The Design of an Intermediate-Frequency System for Frequency-Modulated Receivers*

WILLIAM H. PARKER, JR.†, ASSOCIATE, I.R.E.

Summary—With a possibility that the present frequency-modulation wave band may be increased in width it has become imperative that an intermediate-frequency amplifier operating at a frequency higher than that most commonly in use at present, 4.3 megacycles, be developed. Stability both as to performance and permanence of adjustment govern the choice of frequency and restrict this choice to a definite maximum value. Design data are given in this paper for an amplifier operating on 8.25 megacycles which satisfies the stability conditions, and gives the required performançe.

Introduction

Radio receivers designed for the reception of frequency-modulation broadcasts are usually of the superheterodyne type employing a stage of radio-frequency amplification followed by a frequency converter and with two stages of intermediate-frequency amplification preceding the limiter and frequency discriminator. The band of frequencies assigned to these transmissions, namely, 42 to 50 megacycles, dictates a value of receiver intermediate frequency somewhat greater than 4 megacycles in order to avoid image interference from other frequency-modulation transmissions. With a view to the possibility that the frequency-modulation band may be extended beyond 50 megacycles, and also with an idea of standardizing with television receiver practice, an intermediate-frequency value of 8.25 megacycles in superheterodyne receivers seems in order. This discussion is limited to the problems arising in the design of the intermediate-frequency amplifier when two stages are employed using a frequency of 8.25 megacycles, and to the transformer design problems involved in coupling a limiter to a frequency discriminator.

The Intermediate-Frequency Amplifier

The gain required in the intermediate-frequency amplifier is expressed by the ratio of the voltage needed at the limiter for effective operation (approximately 2 volts) to the voltage appearing at the input to the converter tube from an assumed 5 microvolts at the antenna terminals. The gain is of the order of 40,000 times assuming a total radio-frequency gain of 10.

As a selectivity requirement, the amplifier must allow passage of modulation frequencies to ±100 kilocycles, from the carrier with a minimum of attenuation and then must attenuate as rapidly as possible thereafter. Previous experience with 4.3 megacycles has indicated that an attenuation of 6 decibels, 75 kilocycles removed from the carrier, will result in no observable output distortion. Under this condition, an attenuation of 30 decibels at 200 kilocycles removed from tune can be achieved in design and will result, from a field stand-

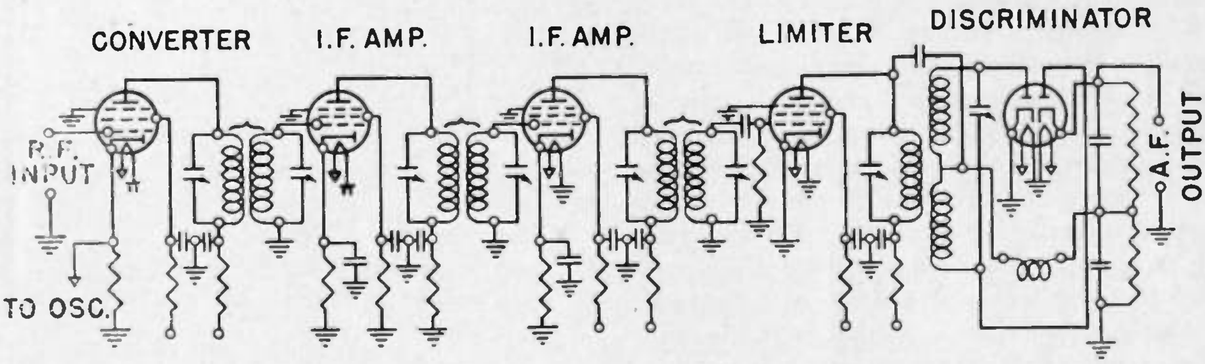


Fig. 1—Schematic for frequency-modulation—intermediate-frequency amplification.

point, in a practical degree of selectivity. These conditions dictate the requirements for an intermediate-frequency amplifier operating at 8.25 megacycles.

Several factors govern the gain and the selectivity of the intermediate-frequency amplifier when the value of the intermediate frequency is established. These are principally (a) the mutual conductance of the amplifier tube and its interelectrode capacitance, (b) the number and Q of the tuned circuits, and (c) the ratio of inductance to capacitance in the tuned circuits.

The mutual conductance of the amplifier tube enters into the gain as a first-order effect. The interelectrode capacitance (i.e., between control grid and plate) acts to limit the maximum gain by introducing regeneration effects.[1]

The gain factor of an amplifier tube may thus be considered as directly proportional to g_m, and inversely proportional to C_{gp}. Three types of tubes have been proposed for amplifier service. A comparison of their

* Decimal classification: R363.1. Original manuscript received by the Institute, July 25, 1944; revised manuscript received, September 25, 1944.
† Stromberg-Carlson Company, Rochester, New York.

[1] J. A. Worcester, Jr., "Double superheterodyne for FM receivers," *FM Magazine*, vol. 4, pp. 15–18, 58–60; March, 1944.

properties may be of interest. The superior properties of the type 6SG7 tubes are obvious and this type was accordingly selected for use in the amplifier.

TABLE I

Tube Type	g_m	C_{gp}	Gain Factor
6SK7	2000	0.003	667
6SG7	4000	0.003	1334
6AC7	9000	0.015	600

The intermediate-frequency amplifier comprises three amplifying tubes, including the converter, and three interstage transformers of double-tuned-circuit design. The schematic is shown in Fig. 1. The individual stage gain is expressed by the relation, when the coupling coefficient k is at the critical value[2]

$$\text{stage gain} = g_m(w\sqrt{L_1L_2}\sqrt{Q_1Q_2})/2$$

g_m = mutual conductance of the amplifying tube
w = angular value of the intermediate frequency
L_1 = inductance of the primary circuit
L_2 = inductance of the secondary circuit
Q_1 = figure of merit of primary circuit
Q_2 = figure of merit of secondary circuit

By design considerations L_1 is made equal to L_2, and Q_1 is made equal to Q_2, which reduces the expression to stage gain $= g_m(wLQ/2)$.

The individual stage selectivity is a function of the circuit Q, and the over-all selectivity requirement previously stated is attained by using appropriate pairs of selective circuits in individual transformers. It then becomes necessary to balance the influence of Q in stage gain against its effect on selectivity. The maximum antenuation requirement of 30 decibels at 200 kilocycles removed from tune resolves to an individual stage attenuation of 10 decibels. By reference to convenient data based on the attenuation as a function of the number and Q of the circuits and deviation from mid-frequency, the required value of Q is found[3,4] to be 45.

The ratio of inductance to capacitance chosen for the tuned circuit is a compromise between amplifier stage gain and stability. The tuning inductance should be high so as to provide adequate stage gain, but on the other hand, the tuning capacitance should be high in order to minimize the effects of changes in capacitance with temperature in the tube, the socket, and the associated wiring. Experience has indicated that not less than 35 micromicrofarads should be included in the total shunt capacitance to allow stable operation and optimum gain. At 8.25 megacycles, the circuit inductance is thus 10.5 microhenries.

The total gain requirement of 40,000 results in an individual stage-gain requirement of slightly more than 34, assuming equal gain in all stages. This is only approximately the case, since the gain in the converter and the gain in the stage preceding the limiter are less than in the normal intermediate-frequency stage. The load conditions in the converter and limiter stages are not the same as in a normal intermediate-frequency amplifier and thus a different adjustment in coupling is required in order that the desired selectivity and gain be realized. Referring to the expression for stage gain, and inserting established circuit constants, a gain of 49 is calculated for the interstage intermediate-frequency amplifier. This result was experimentally verified. By suitable adjustment of coupling, a conversion gain of 27 was realized, and in the stage preceding the limiter a gain of nearly 30 was obtained. The net over-all gain is thus computed to be 39,800 which is in close agreement with the specification.

The Intermediate-Frequency Transformer

Experimental work led to the development of intermediate-frequency transformers embodying the circuit constants enumerated. The data are tabulated as follows:

Coil form diameter . . . . $\frac{5}{16}$ inch
Wire size . . . . no. 36 B&S gauge enamel
Type of winding . . . . solenoid, single layer
Number of turns (primary) 32
Number of turns (secondary) 32
Distance between inside turns of windings . . 23/64 inch
Shield container . . . . . . $1\frac{3}{8}$ inches square on sides
Q of windings, in air 75

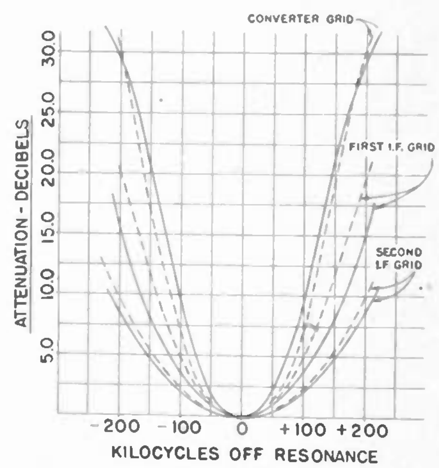


Fig. 2—Selectivity characteristic 8.25-megacycle intermediate-frequency amplifier.

The measured gain of the first intermediate-frequency stage with the transformer described was 55, and that of the second stage (operating into the limiter) was 31. The selectivity characteristics of one, two, and three stages, both calculated and measured are shown in Fig. 2. The selectivity is measured between the second intermediate-frequency-amplifier grid and the limiter input, between the first intermediate-frequency-amplifier grid and the limiter input, and between the converter grid and the limiter input as indicated.

A word might be said as to the need for electrostatic shielding between transformer windings. In the absence of a shield, the capacitive coupling in the design

[2] F. E. Terman, "Radio Engineers' Handbook," McGraw-Hill Book Company, New York 18, N. Y., 1943, section 5, paragraph 19.
[3] See section 3, paragraph 5, of footnote reference 2.
[4] "Radiotron Designer's Handbook" (third edition) edited by F. Langford Smith, published by Wireless Press for Amalgamated Wireless Valve Company, Sydney, Australia, 1942, p. 128.

described is approximately the same order of magnitude as the inductive coupling. Capacitive coupling makes difficult the attainment of a symmetrical selectivity curve. Also effective coupling between the windings

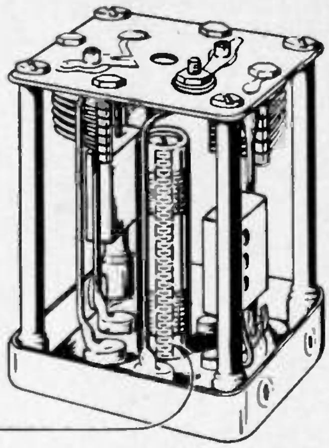


Fig. 3—Intermediate-frequency transformer, 8.25 megacycles.

changes rapidly with spacing and the desired coupling is difficult to obtain and to maintain in production. The simple expedient of a brass screw inserted axially in the coil and connected to a frame proved a satisfactory means of minimizing the disturbing electrostatic coupling. A typical transformer construction is shown in Fig. 3.

The Discriminator Transformer

Derivation of the audio voltage from the frequency-modulated signal is accomplished in the discriminator network following the limiter. Due to its simplicity and ease of adjustment, the well-known Foster-Seeley circuit is used. A transformer for this service was designed. Its specifications follow:

Coil-form diameter .... $\frac{1}{4}$ inch
Wire size (primary and secondary) ....
.... no. 38 B&S gauge single silk enamel
Type winding (primary) .... universal (64/66 gears)
Type winding (secondary) .... solenoid, single layer
Number of turns (primary) 35
Number of turns (secondary) 58
Shield container .... $1\frac{3}{8}$ inches square on sides
Q of primary in air 35
Q of secondary in air 65

The voltage-input versus output-frequency change is shown in Fig. 4. These data were obtained by intro-

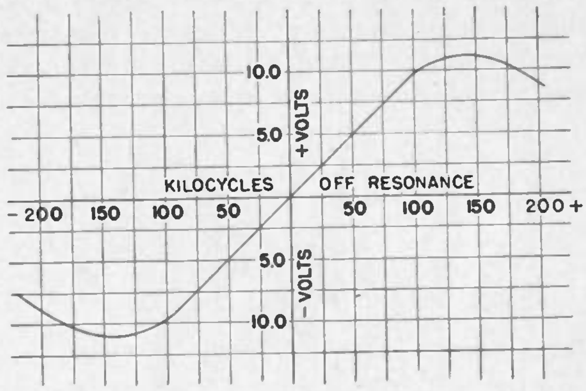


Fig. 4—Discriminator characteristic, 8.25 megacycles.

ducing a frequency-modulated source at the limiter grid and observing the direct-current change in the discriminator output as the modulation index was changed. A carrier level of 2 volts input was used. The characteristic is observed to be linear to ±75 kilocycles from the center frequency, with some departure from linearity between ±75 to 100 kilocycles from the center frequency.

Conclusion

The intermediate-frequency amplifier of the design described was installed in several experimental receivers previously designed for 4.3-megacycle operation. Satisfactory results were obtained. The receivers were uniform in performance, and indications are that no difficulties due to instability will arise when the receivers are built in production.

Triode Linear Saw-Tooth-Current Oscillator*

LEONARD R. MALLING†, ASSOCIATE, I.R.E.

Summary—**It is shown that a triode may be used for generating a linear saw-tooth current when coupled to a suitably designed transformer. The triode is operated on a hitherto unused portion of the E_p/I_p characteristics, notably the positive-grid region where the E_p/I_p characteristic is a straight line of slope $R = E_p/I_p$. While the over-all efficiency of the oscillator is low, it is shown to be inherently more efficient than conventional scanning systems operating in the negative-grid region. Improved operating conditions and circuit efficiency may be obtained by the use of an inverted diode. The losses in a typical triode-scanning oscillator are analyzed and individually computed for a given design. Attention to these individual circuit losses should enable designs to be made of considerably higher efficiency.**

* Decimal classification: R355.9. Original manuscript received by the Institute, February 23, 1944; revised manuscript received, July 24, 1944; revised manuscript received, September 25, 1944.

† 127 Argyle Pl., Seattle 3, Washington.

Many diverse methods are used for the generation of saw-tooth currents for sweeping cathode-ray tubes. It is not generally realized, however, that a triode vacuum tube using a suitably designed magnetic and electric circuit is capable of producing a linear sweep with a high degree of efficiency and simplicity of circuit design. Like the triode sine-wave oscillator, the frequency and wave-form characteristics are almost completely determined by the feedback transformer design. The use of the triode oscillator for magnetic scanning was first proposed by Philo T. Farnsworth,[1] modifications being made later by other workers in the field, notably G. R. Tingley and A. H. Gilbert.

[1] U. S. Patent No. 2,059,683, November 3, 1936.

The salient design features that affect linearity and efficiency will be discussed in detail with an analysis of the tube operation.

Description of Basic Circuit

Fig. 1 shows the basic circuit of the triode saw-tooth-current generator. The ratio of L/C is high and the two windings of the transformer are tightly coupled on a closed iron core. Oscillations in circuits of this type were first discussed in a paper by Vecchiacci[2] who presented oscillograms showing that while the plate and grid voltages would exhibit pulse characteristics the plate

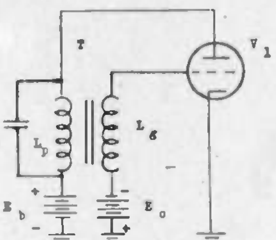


Fig. 1—Basic saw-tooth current-generator circuit.

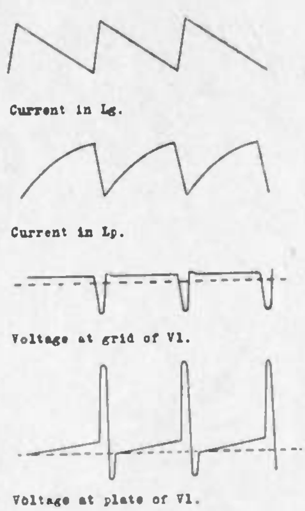


Fig. 2—Current and voltage wave forms in circuit of Fig. 1.

and grid currents would be of substantially saw-tooth wave form. Operation of this class of oscillator is characterized by two modes of oscillation, a vigorous single sine-wave-voltage oscillation of frequency given by $|\omega^2| = 1/LC$ followed by a period of heavy grid current lasting several such cycles during which these voltage oscillations are effectively damped out and a saw-tooth current generated. The length of this damped period which fixes the frequency of the saw-tooth current oscillations is determined chiefly by the transformer design but is also influenced by the applied bias. The sine-wave-voltage oscillation frequency is determined entirely by the LC product of the circuit components. These two modes of oscillation are illustrated in Fig. 2 which gives the voltage and current waveforms existing in the basic circuit.

Fig. 3, an equivalent of circuit for Fig. 1, shows the manner in which the vacuum tube acting as a switch changes from the heavily damped period t_1 to the short oscillatory period t_2. When the switches are closed C is quickly charged and a high current established in R_g. Then, as current is gradually established in L_p, the voltage across it drops, and the current in R_g drops. If L_p is replaced by a two-winding transformer, I_p starts as the reflected I_g and increases. I_g starts as some high

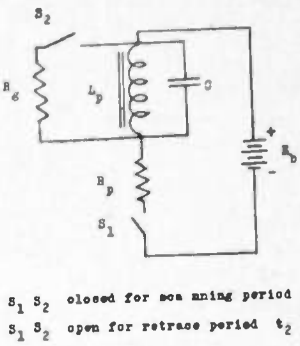


Fig. 3—Equivalent circuit for saw-tooth-current oscillator.

value and decreases. The period t_1 may be considered as a long direct-current charging period in which the plate current increases exponentially through the inductance L_p which will induce a similar current in L_g. However, owing to the grid-current characteristics of the vacuum tube, the current in L_g does not follow exactly the plate-current variations. Assuming for the moment a linearly falling current in L_g a steady positive potential e_g will be induced across L_g given by

$$e_g = -L_g(di_g/dt). \quad (1)$$

The bias is set so that this voltage drives the tube into the positive-grid region for the whole of the scanning period t_1. The I_p/E_p characteristics of a typical triode operating in the positive-grid region are shown in Fig. 4

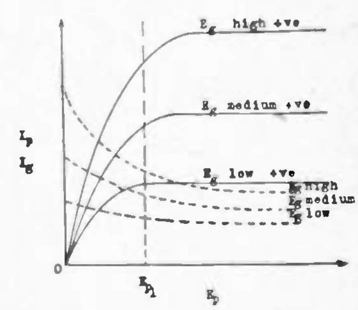


Fig. 4—Plate-current—plate-voltage and grid-current characteristics for the positive-grid region.

and the operating region that is of interest for our purpose lies between zero plate voltage and the voltage indicated by the dotted line E_{p_1} representing a scanning-time excursion t_1. Over this part of the characteristic the tube is acting substantially as a pure resistance with an equation of the type $R_p = E_p/I_p$ being satisfied. The plate and grid impedance will be of the order of a few hundred ohms for triodes of the power-output class. However, it will be noted that the grid impedance given by

$$r_g = \partial e_g/\partial i_g \quad (2)$$

changes markedly over the working region defined, so

[2] F. Vecchiacci, "Oscillations in the circuit of a strongly damped triode," Proc. I.R.E., vol. 19, pp. 856–873; May, 1931.

that as I_p rises r_g rises and thus accelerates the falling off of the grid current. By suitable choice of circuit parameters the current in L_g can be made to decrease linearly. The effect of grid loading on I_g is shown in Fig. 5.

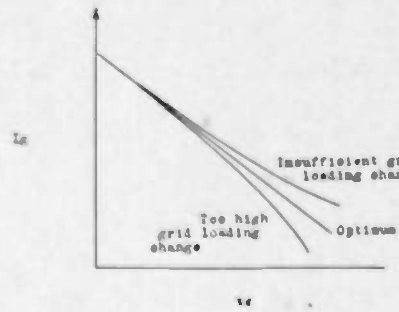


Fig. 5—Effect of variable-grid loading on secondary current in transformer.

Application of Triode Oscillator to Scanning Problems

In order to utilize the saw-tooth current existing in the transformer windings, some form of magnetic circuit is required to enclose the cathode-ray tube neck. The leakage flux may be used direct as shown in Figs. 6a and 6b, or separate scanning coils may be used as shown in Fig. 6c. A typical triode-oscillator circuit designed for

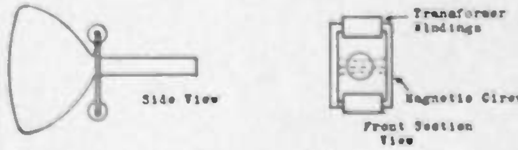


Fig.6a. Magnetic Circuit using Closed Yoke.

Fig.6b. Magnetic Circuit using Open Yoke.

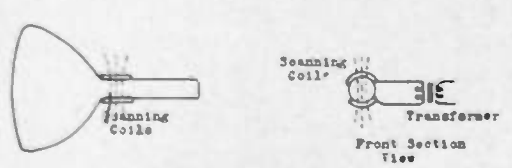


Fig 6c. Use of Separate Scanning Coils.

Fig. 6—Types of magnetic circuit for use with cathode-ray tube.

high-scanning frequencies is shown in Fig. 7 and functions in general like the basic circuit of Fig. 1 except that the diode rectifier modifies the behavior of the voltage oscillation and separate scanning coils are used. The capacitance C of Fig. 1 now becomes the sum of the tube and stray capacitances, making the L/C ratio as high as is practically possible. The negative-plate excursion of Fig. 2(d) is now eliminated by the diode as when the plate swings negative the diode draws current thus charging the capacitance C. The energy so obtained is available for conversion into the magnetic field of the scanning coils, see Fig. 8. The energy relation is given by

$$W_s = 1/2\, C E_s^2 \text{ joules} \tag{3}$$

where

$$E_s = -L_s(di_s/dt) \tag{4}$$

and L_s is the scanning-coil inductance and i_s the scanning-coil current. Heater current for the diode may be taken direct from the scanning transformer when the heater-power requirements are low. Negative bias to the

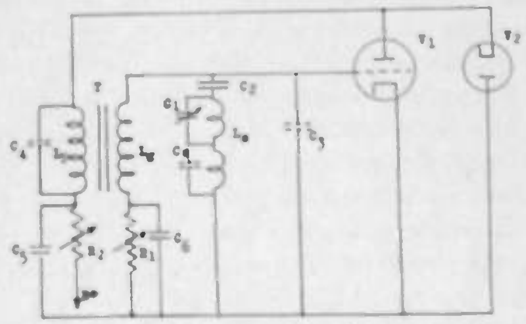


Fig. 7—Schematic diagram of typical scan oscillator designed for high scan frequency.

C_1 added capacitor to balance C.
C_2 coil coupling
C_3, C_4 stray capacitance
C_5, C_6 by-pass capacitors
L_s scanning coils
R_1 scan-frequency control
R_2 scan-amplitude control

triode is supplied by the direct-current drop in the variable resistor R_1 which is by-passed for scanning currents. The resistor R_2 is used for control of scan amplitude. Fine control of scanning frequency is obtained by adjustment of R_1. Increased bias decreases the excursion into the positive-grid region shortening the time over which the plate-current swing is linear and decreasing the linear charging period t_1. This gives a higher scanning frequency and vice versa. The retrace time will remain constant, being controlled entirely by the LC components so that the percentage retrace time will vary with scanning frequency. Synchronization is best accomplished by coupling direct to the grid through a diode and using a negative synchronizing pulse. By connecting the diode plate direct to the grid negative synchronizing pulses pass to the grid but negative oscillation potentials are prevented from passing back into the synchronizing circuits. In cases where precise timing is not important a third winding may be added to the transformer and coupled in the plate circuit of the synchronizing tube in such phase as to give the required negative synchronizing pulse at the grid of the triode.

An attempt is made in the following brief analysis of

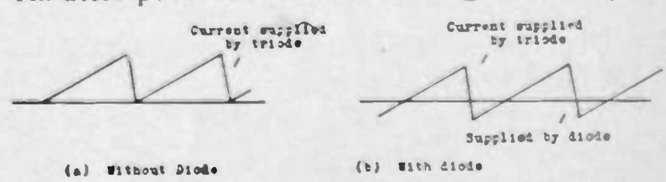


Fig. 8—Part of the scanning current is supplied by efficiency diode of Fig. 7.

circuit losses to show how power is dissipated in the various circuit components and the relation that these circuit losses have to the power actually used for scanning. The losses and efficiency of the circuit of Fig. 7 may be conveniently analyzed by means of the equivalent circuit diagram of Fig. 9. The effective load on the oscillator will be the grid resistance of the vacuum tube, and it is this load which is the effective plate load of the oscillator tube when considering power relationships. The scanning coils may be considered as a factor affecting the power factor only when considering total losses. For constant grid voltage and zero leakage reactance in the transformer maximum power into r_g will be delivered by the generator of Fig. 9 when $r_p = r_g$, X_{L_s} and X_c being assumed high. However, the leakage inductance L_e modifies this relationship so that maximum power would be delivered when $r_g = X_{L_e}$. The leakage reactance is usually sufficiently high to prevent the latter from being realized as too high a transformer ratio would be required making the effective C too high. The ratio should also be kept low so that the ratio of leakage

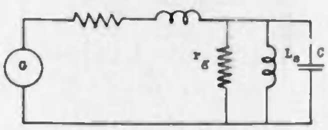


Fig. 9—Equivalent circuit for high scanning frequency. 1:1 transformer ratio assumed.

reactance to coil inductance L_s is low in order to minimize loss of the reactive scanning power.

The ratio of the current in the load without matching to the load current with perfect matching is given by

$$k = \frac{[4r_p/(r_g + jX_{L_e})]^{1/2}}{1 + [r_p/(r_g + jX_{L_e})]}. \qquad (5)$$

Some knowledge of the circuit constants is necessary to determine the losses and the circuit efficiency. The scanning-coil inductance is given by

$$L_s = 1/\omega_0^2 C \text{ henries} \qquad (6)$$

where ω_0 is given by

$$f_0 = 1/2t_2 \qquad (7)$$

and t_2 is in seconds.

The field intensity required to deflect the beam through half the total scanning angle is given by

$$H = 3.36V^{1/2} \sin \beta / l_c \text{ gauss} \qquad (8)$$

where β is the half-scan angle, V the second anode potential, and l_c the coil length.

The ampere-turns required in the scanning coils to produce this field

$$NI_s = (1/0.4\pi)Bl_g. \qquad (9)$$

$B = H$ for this particular case where the field is in air.

The mean length of the gap

$$l_g = \pi d/4 \text{ approximately} \qquad (10)$$

where d is the over-all diameter of the cathode-ray tube neck. Knowing the number of turns in the coil enables the coil current to be determined and allowing for the transformer ratio the peak tube plate current can be found

$$I_{L_p} = I_s/n. \qquad (11)$$

The positive-grid potential to give a linear relation E_p/I_p over this plate-current range can be found from the tube characteristics.

The over-all efficiency of a scanning system may be defined as the ratio of the power required to sweep the beam to the input power delivered to the scanning system. The energy required to sweep the beam in one direction per cycle

$$W_s = (1/2)L_s I_s^2 \qquad (12)$$

where I_s = root-mean-square saw-tooth current and $I_{rms} = I_{max}/\sqrt{3}$. The power used for creating the magnetic field at a frequency f_s is given by

$$P_s = f_s W_s \text{ watts.} \qquad (13)$$

The input power to the system is of course given by the product $E_b I_p$ direct current and the difference between this figure and that given by (13) represents the losses. These losses may be broken down into those introduced by the transformer, tube losses, and mismatch losses.

At low frequencies the transformer losses in a scanning system are mostly copper losses and at high frequencies mostly iron losses. The core loss is the sum of the eddy current and hysteresis losses $W_c = W_e + W_h = K_h f_s + K_e f_s^2$ where K_h and K_e are hysteresis and eddy-current factors dependent on the iron used. The eddy current losses $W_e = (\pi^2/6\rho)b^2 f_s^2 B_{max}^2 10^{-14}$ watts per cubic centimeter and the hysteresis losses $W_h = nf_s B_{max}^{1.6} 10^{-7}$ watt per cubic centimeter where t = thickness of laminations meters, B_{max} gauss, ρ = ohmmeters, n = a constant, which for silicon steel may be taken as 0.001. A useful approximation for the core losses may also be made by extrapolation of the manufacturer's curves given for lower frequencies.

The tube losses are the plate loss

$$W_p = (I_{max}^2/3)R_p \qquad (14)$$

and the grid loss

$$W_g = I_{av}^2 R_g. \qquad (15)$$

The mismatch losses are given by (5).

Practical Design

A preliminary series of approximations will be made on a typical design to indicate the nature of the problem involved and the magnitude of the various losses. The data are shown in Table I.

TABLE I

Scanning frequency	15,000 cycles per second, 10 per cent retrace time
Cathode-ray tube	7 CP1
Triode oscillator tube	6L6 triode-connected
Second anode potential	7000 volts
Length of trace	6 inches
Scanning-coil length	2 inches
Scan transformer	1.4-to-1 ratio, cross-section area 1 square inch, core length 5½ inches

The circuit to be used will be identical with that shown in Fig. 7.

The energy required to sweep the beam at 15,000 cycles per second will first be determined. To do this the scanning-coil inductance and the root-mean-square saw-tooth current flowing in the coils must be evaluated. The frequency of the free oscillation period $f_0 = 75$ kilocycles from (7) and assuming $C = 100$ micromicrofarads the scanning-coil inductance $L_s = 45$ millihenries from

(6). The scanning-coil current can be determined from a knowledge of the magnetic scanning field and the turns comprising the scanning coils. From handbook data on the 7 CP1 and the length of trace given above, the half-scan angle becomes 23 degrees for a radius of deflection of 7 inches. Thus from (8) $H = 21.6$ gauss, or the total field required for full sweep is 43.2 gauss. From (9) and (10) 95 ampere turns are required in the scanning coils for creating this field of 43.2 gauss. Assuming simple square scanning coils of square cross section bent to fit the tube neck and surrounded by a thin circular iron shield the total number of turns may be estimated at 740. This gives a peak current of 128 milliamperes or a root-mean-square saw-tooth current of 74 milliamperes. Thus from (12) the energy required to sweep the beam $W_s = 124$ microjoules and the power used for creating the field at a frequency of 15,000 cycles is 1.86 watts from (13).

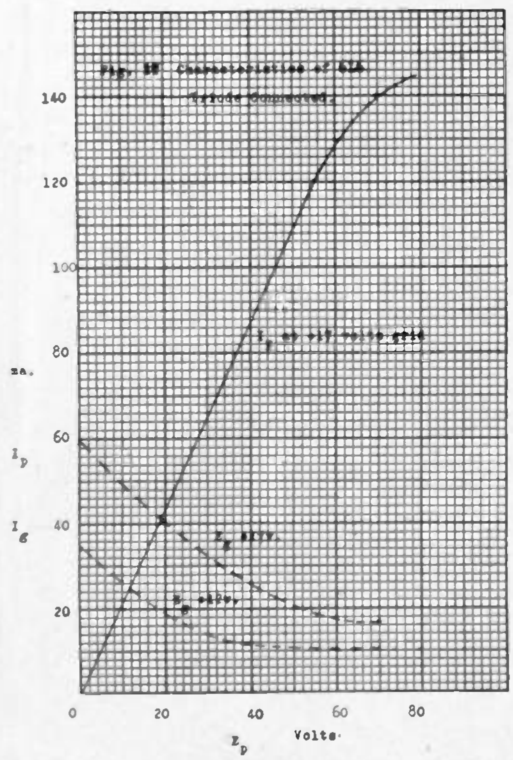


Fig. 10—Characteristics of 6L6. Triode connected. Positive bias.

It will be of interest to see how much of the energy required to sweep the beam is supplied by the diode. From (4) the voltage developed across the scan coils $E_c = 860$ volts so that the energy stored $W_c = 37$ microjoules or 30 per cent of the total scanning-power requirements.

The correct operating characteristics for the oscillator tube may now be considered. The peak current flowing in the primary or plate winding of the transformer allowing for the 1.4-to-1 transformer ratio will be 92 milliamperes. The positive bias required to obtain a substantially linear I_p/E_p relationship up to this current for the 6L6 is of the order of 17 volts, and Fig. 10 shows an E_p/I_p curve for the 6L6 with these conditions. Corresponding grid-current curves are also shown. From these curves it can be seen that $R_p = 470$ ohms and that the grid resistance varies from 200 to 400 ohms.

Some estimate of the leakage inductance must be made before the total losses are calculated and a brief outline of a typical scan transformer will be of interest in this connection. The grid inductance of the transformer should be several times that of the scanning coils to avoid shunting effects, say 0.45 henry so that the plate inductance will be 0.9 henry. A preliminary approximation for the number of turns required on a 1-inch square core to give the required inductance of 0.9 henry gives 800 turns. This may be checked by determining the inductance given by this number of turns when carrying the direct plate current and saw-tooth current. The direct plate current will be of the order of 70 milliamperes so that the polarizing magnetomotive force $H_0 = 5$ gilberts per centimeter ($l = 14$ centimeters) giving an incremental permeability of 400 for standard audio A laminations. The flux density $B_{max} = (E_{rms}10^8)/(4.44f_sN_pAK_A)$. Now $E_{rms} = E_{max}(t_1/t_1+t_2)^{1/2} = 380$ volts. $E_{max} = 1.4 \times 860$, the grid voltage times the transformer ratio. So that $B_{max} = 125$ gauss. The plate inductance calculates out to be close to the required figure of 0.9 henry with this flux density. Using suitable formulas[3] the leakage inductance may be determined and may be approximated at 55 millihenries.

The separate losses may now be calculated and summed. The mismatch loss due to the leakage reactance will be figured for best match at the highest working grid impedance which is 400 ohms. The plate resistance is 470 ohms and the load impedance is the sum of the grid resistance and the leakage reactance, that is 5200 ohms, so that from (5) $k = 0.55$ giving a loss of 5 decibels or a power loss ratio of 3.16. The power loss at the grid E^2/R_g is 1 watt, where E is the positive grid voltage developed at the grid during the scanning time. The plate power loss is $I_{rms}^2r_p$ giving a figure of 2.5 watts. Losses in the grid resistor can be determined from the difference between the positive grid voltage developed and the positive bias required for correct grid operation. The positive bias developed by the flow of saw-tooth current through the grid inductance is 96 volts and the required fixed grid potential is 17 volts positive. From the tube characteristics the average direct current is 40 milliamperes and thus the grid resistor power loss is 3.75 watts. Summing the above it can be seen that the total plate power required to drive the grid circuit will be 12 watts. Core losses calculate out at 2 watts and extrapolated data give 3 watts, but experience indicates a figure of from 3 to 4 watts for a scanning frequency of 15 kilocycles. The total of these losses gives a figure of 18 watts, and as the power required to sweep the beam in one direction is of the order of 1.8 watts the over-all efficiency of the scanning oscillator is 10 per cent.

[3] Harold Pender and Knox McIlwain, "Electrical Engineers' Handbook," vol. 5, John Wiley and Sons, New York, N. Y., 1936, section 5 to 21.

Impulse Excitation of a Cascade of Series Tuned Circuits*

SAMUEL SABAROFF†, ASSOCIATE, I.R.E.

Summary—The response of a cascade of series tuned circuits to an impulse is mathematically determined. The peak value of this response is examined and found to be approximately $E=SG(\omega_2-\omega_1)/2$ where S=impulse strength, G=network gain at the resonant frequency ω, and $(\omega_2-\omega_1)$ is the bandwidth at 0.707 down on the voltage characteristic. This peak value is relatively independent of the number of tuned circuits when $5<n<Q/2$ where n=number of tuned circuits and $Q=\omega L/R$.

THE elementary noise is that resulting from a single impulse. All other noises may be considered to be the result of combinations of such impulses. Radio devices in which noise manifests itself are usually composed of cascaded tuned circuits. An analysis of the response of a network composed of a cascade of simple series-resonant circuits to an impulse is therefore fundamental in the study and measurement of noise.

The noiselike qualities of the network response to an impulse is determined in large part by the peak[1] value of this response. Variation in the shape of an impulse has relatively little effect provided its duration is small with respect to the natural period of the excited circuit.[2]

It has been stated and experimentally verified that the peak value of the network response to an impulse is proportional to the effective over-all bandwidth.[3] The following mathematical analysis formally verifies this fact subject to certain conditions.

The differential equation of a simple series-resonant circuit in terms of the condenser voltage is

$$LC(d^2v_1/dt^2) + RC(dv_1/dt) + v_1 = V \qquad (1)$$

where V=applied voltage.

Assuming an initial condition of equilibrium,[4–6] the Laplacian solution of (1) is

$$\bar{v}_1 = \overline{V}/(LCp^2 + RCp + 1) \qquad (2)$$

where the bar indicates the operation of multiplying by e^{-pt} and taking the infinite integral with respect to t.

For example

$$\bar{x} = \int_0^\infty e^{-pt}x(t)dt \qquad (3)$$

where $|p|>0$.

The network is assumed to be a cascade of simple series-resonant circuits as shown in Fig. 1, with the voltage across the condenser of each circuit taken to be the driving force for the next. The reaction of each circuit on the preceding one is taken to be zero.

The Laplacian solution for the voltage across the condenser in the nth circuit is then

$$\bar{v}_n = \overline{V}/(LCp^2 + RCp + 1)^n. \qquad (4)$$

Equation (4) may be written

$$\bar{v}_n = \overline{V}/\{(LC)^n[(p+\alpha)^2+\beta^2]^n\} \qquad (5)$$

where $\alpha=R/(2L)$ and $\beta=\sqrt{(1/LC) - R^2/(4L^2)}$.

Equation (5) is a formal solution with no restrictions other than those required by Laplacian theory.

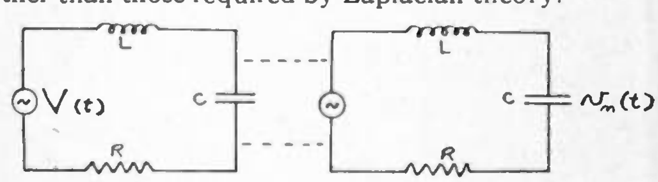


Fig. 1—Cascaded series-resonant circuits.

The driving force is taken to be an impulse occurring at $t=+0$. The Laplacian of such an impulse is a constant called the strength of the impulse; thus

$$\overline{V} = S \qquad (6)$$

where S is the impulse strength.

Equation (5) now can be written

$$(LC)^n\bar{v}_n/S = [(p+\alpha)^2+\beta^2]^{-n}. \qquad (7)$$

Equation (7) may be solved without great difficulty for $v_n(t)$ by purely mathematical means. However, various Laplacians and their inverses have been tabulated. The more practical method would be to peruse these tabulated forms for a possible solution. First, however, (7) can be somewhat simplified by applying the principle of translation,

$$(LC)^n\overline{[e^{\alpha t}v_n(t)]}/S = (p^2+\beta^2)^{-n}. \qquad (8)$$

The right-hand side of (8) and its inverse have been tabulated.[7] They are

$$\frac{\sqrt{\pi}}{\Gamma(n)(2\beta)^{n-1/2}}\overline{[t^{n-1/2}J_{n-1/2}(\beta t)]} = (p^2+\beta^2)^{-n} \qquad (9)$$

where $n>0$, and $J_{n-1/2}(\beta t)$ is a Bessel function of the first kind.

Equating (9) and (10), removing the bars and solving for $v_n(t)$ results in the complete solution

* Decimal classification: R142. Original manuscript received by the Institute, February 11, 1944; revised manuscript received, September 18, 1944.

† WCAU Broadcasting Company, Philadelphia, Pennsylvania. This work was done for Lucian Laboratories, Lansdowne, Pennsylvania, for whom the author was consultant.

1 C. M. Burrill, "Progress in the development of instruments for measuring radio noise," Proc. I.R.E., vol. 29, pp. 433–441; August, 1941.

2 John R. Morecroft, "Principles of Radio Communication," John Wiley and Sons, Inc., New York, N. Y., 1927, chapter 3.

3 V. D. Landon, "A study of the characteristics of noise," Proc. I.R.E., vol. 24, pp. 1514–1521; November, 1936.

4 H. S. Carslaw and J. C. Jaeger, "Operational Methods in Applied Mathematics," Oxford University Press, London, England, 1943.

5 Murray F. Gardner and John L. Barnes, "Transients in Linear Systems," vol. 1, John Wiley and Sons, Inc., New York, N. Y., 1942.

6 R. V. Churchill, "Modern Operational Mathematics in Engineering," McGraw-Hill Book Company, New York 18, N. Y., 1944.

7 See transform 57 on page 298 of footnote reference 6.

$$v_n(t) = \frac{St^{n-1}e^{-\alpha t}}{(LC\beta)^n 2^{n-1}\Gamma(n)}\sqrt{\frac{\pi\beta t}{2}}\,J_{n-1/2}(\beta t). \qquad (10)$$

β may be real, zero, or imaginary, depending on whether the circuits are oscillatory, critically damped, or aperiodic. We will here consider real values of β only.

The Bessel function in (10) may be written in terms of circular functions[8] thus lending itself to more evident analysis;

$$\sqrt{\pi\beta t/2}\,J_{n-1/2}(\beta t) = P_n(\beta t)\cos(\beta t - (n\pi/2)) - Q_n(\beta t)\sin(\beta t - (n\pi/2)) \qquad (11)$$

where n is an integer and

$$\left.\begin{aligned} P_n(\beta t) &= \sum_{r=0}^{\infty} \frac{(-1)^r \lfloor n-1+2r}{\lfloor 2r \lfloor n-1-2r\,(2\beta t)^{2r}} \\ Q_n(\beta t) &= \sum_{r=0}^{\infty} \frac{(-1)^r \lfloor n+2r}{\lfloor 2r+1 \lfloor n-2r-2\,(2\beta t)^{2r+1}} \end{aligned}\right\}. \qquad (12)$$

P_n and Q_n are terminating series, since for sufficiently large values of r, the factorial of a negative integer appears in the denominator and such a factorial is equal to infinity.

As a first approximation for values of $\beta t > n^2$, it will be sufficient to consider only the leading terms in (12). Making these substitutions in (10) gives

$$v_n(t) = \frac{St^{n-1}e^{-\alpha t}}{(LC\beta)^n 2^{n-1}\lfloor n-1}\left[\cos\left(\beta t - \frac{n\pi}{2}\right) - \frac{n(n-1)}{2\beta t}\sin\left(\beta t - \frac{n\pi}{2}\right)\right]. \qquad (13)$$

Let us now assume the circuits sufficiently oscillatory as to make $\alpha \ll \beta$. The value of β then approaches the fundamental resonant frequency of the circuits, which we shall call ω. Thus

$$\beta \cong \omega = 1/\sqrt{LC}. \qquad (14)$$

Equation (13) may now be written, approximately

$$v_n(t) = \frac{S\omega^n t^{n-1}e^{-\alpha t}}{2^{n-1}\lfloor n-1}\left[1 + \frac{n^2(n-1)^2}{8(\omega t)^2}\right]\cos\left[\omega t - r - \frac{n\pi}{2}\right] \qquad (15)$$

where

$$\sin(r) \cong -n(n-1)/(2\omega t)$$
$$\cos(r) \cong 1 - n^2(n-1)^2/(8\omega^2 t^2).$$

Examination of (15) shows that it represents a sinusoid of varying amplitude and phase. We shall consider in some detail the amplitude characteristics only. The peak value of this sinusoid may be found by differentiating the amplitude with respect to time and equating to zero, thus discovering the necessary conditions. Substantial simplification occurs when it is remembered that the assumption of $\omega t > n^2$ has been made. Let us now specify that the change in amplitude due to the quadrature component be less than 1 per cent; i.e.,

$$n^2(n-1)^2/(8\omega^2 t^2) < 1/100. \qquad (16)$$

We may, therefore, omit this term in (15) without substantial error, provided the conditions for the peak value satisfy the above inequality.

Differentiating the remaining time functions in the amplitude and then equating to zero gives

$$d(t^{n-1}e^{-\alpha t})/(dt) = 0 \quad \text{when} \quad t = (n-1)/\alpha. \qquad (17)$$

Substituting the condition of (17) into (16) results in the inequality

$$n\alpha/(2\sqrt{2}\,\omega) < 1/10. \qquad (18)$$

Putting $R/(2L)$ for α, and Q for $L\omega/R$ in (18) gives finally $n < 0.566Q$, or rounding off

$$n < Q/2 \qquad (19)$$

as the relation to be satisfied for the quadrature component to be negligible in the region of the peak value and for times thereafter. This condition exists in most practical circuits. For these circumstances (15) becomes

$$v_n(t) = \frac{S\omega^n t^{n-1}e^{-\alpha t}}{2^{n-1}\lfloor n-1}\cos\left(\omega t - \frac{n\pi}{2}\right). \qquad (20)$$

Recourse must be had to (10) or (11) if accurate values of $v_n(t)$ are desired for times less than that at which the maximum value occurs or when the inequality of (19) is not observed.[9]

If we let E be the peak value of (20), then utilizing the condition of (17), we have

$$E = \frac{S\omega^n(n-1)^{n-1}e^{-(n-1)}}{(2\alpha)^{n-1}\lfloor n-1}. \qquad (21)$$

For large values of n, (21) may be simplified by utilizing the Stirling approximation for the factorial

$$\lfloor n-1 = (n-1)^{n-1}e^{-(n-1)}\sqrt{2\pi(n-1)} \qquad (22)$$

becoming thereby

$$E = S\omega^n/[(2\alpha)^{n-1}\sqrt{2\pi(n-1)}]. \qquad (23)$$

The Stirling approximation is 2 per cent low for $n=6$ and 1 per cent low for $n=10$, becoming more accurate with increasing values of n.

Equation (23) may be further simplified by putting in the value for α,

$$E = SRG/[L\sqrt{2\pi(n-1)}] \qquad (24)$$

where G is the total gain of the network $= (\omega L/R)^n$. The value of G can also include any linear external amplification that may be present between the various circuits.

Equation (24) is now in terms of easily measurable quantities. The response of the network to a sine wave of frequency ω will determine the value of G. R/L can be determined by measuring the Q of one circuit. In this case (24) is

$$E = \omega SG/[Q\sqrt{2\pi(n-1)}]. \qquad (25)$$

It may be more convenient to determine the ratio R/L by noting a relation between the attenuation and frequency of the whole network. It can be shown that for $\alpha \ll \omega$,

[8] S. A. Schelkunoff, "Electromagnetic Waves," D. Van Nostrand Company, Inc., New York, N. Y., 1943, pp. 51–52.

[9] E. Jahnke and F. Emde, "Tables of Functions," B. G. Teubner, Leipzig and Berlin, Germany, 1933, pp. 222–227.

$$R/L = (\omega_2 - \omega_1)/\sqrt{A^{2/n} - 1} \tag{26}$$

where $(\omega_2 - \omega_1)$ is the bandwidth at a point on the voltage characteristic that has a relative attenuation of A, with the minimum attenuation taken as unity.

Incorporation of (26) in (24) gives

$$E = SG(\omega_2 - \omega_1)/\sqrt{2\pi(n-1)(A^{2/n} - 1)}. \tag{27}$$

It is interesting to note that the denominator of (27) approaches a limit as n increases without limit. By ordinary methods it can be shown that

$$\lim_{n\to\infty} (n-1)(A^{2/n} - 1) = 2 \log (A) \tag{28}$$

then

$$E = SG(\omega_2 - \omega_1)/[2\sqrt{\pi} \log (A)]. \tag{29}$$

When, as is usual, A is made equal to $\sqrt{2}$, (29) is

$$E = 0.48SG(\omega_2 - \omega_1). \tag{30}$$

The numerical factor of 0.48 in (30) applies when $n \to \infty$. For $n=5$ and $n=10$, as calculated by means of (27), this factor is 0.52 and 0.50, respectively. For values of $n>5$, the factor may be rounded off and made equal to 0.5. Equation (30) becomes finally

$$E = SG(\omega_2 - \omega_1)/2 \tag{31}$$

with a maximum probable error of less than 10 per cent when $5 < n < Q/2$.

A Calculator for Two-Element Directive Arrays[*]

J. G. ROUNTREE[†], MEMBER, I.R.E.

Summary—**This article describes a mechanical device which may be used to calculate quickly the horizontal field pattern of a two-element directive array. The construction is not difficult and may readily be undertaken with only the usual drafting instruments, a protractor, and a set of mathematical tables.**

Introduction

AS THE number of standard broadcast stations has increased, more and more recourse has been made to the use of directive arrays to minimize interference to other stations operating on the same channel. The design and adjustment of these arrays has become a somewhat specialized field of consulting radio engineering, requiring as it does, a background of training and experience not usually found among the personnel of broadcast stations, and the use of instruments not always in possession of these stations.

This article describes a mechanical device which may be used to calculate quickly the horizontal field pattern of a two-element directive array.[1] While allocation problems in assignments of a number of recent stations have required that arrays of three or more elements be used, many existing directive arrays consist of only two elements. The calculation of the horizontal field pattern for a two-element array, although laborious, is not a too-difficult feat mathematically, and many patterns for these arrays are available for use as a starting point or as a guide.[2–4] However, it is felt that the calculator described herein can serve a useful purpose in determining the parameters for new directional installations and in determining the effects of changes in parameters of existing arrays, thereby enabling those who operate with such an array to observe the effect of a maladjustment of current or phasing on the horizontal pattern. The construction of this device is not difficult and may readily be undertaken with only the usual drafting instruments, a protractor, and a set of mathematical tables.

Principle of Operation

The principle upon which this device operates is that of vector solution. Fig. 1 indicates an array consisting

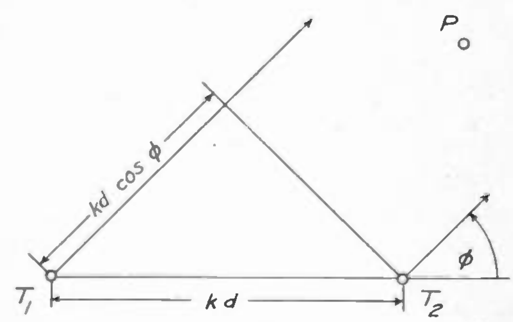


Fig. 1—Plan view of two-element array.

of two identical towers, spaced an electrical distance ***kd*** degrees. At any point within the field of the antenna system, the field-strength component due to each element will be directly proportional to the current in that element, and the resultant field strength will be the resultant of the two voltage vectors at that point. Point P is located sufficiently distant so that signals from the towers travel over substantially parallel paths. Assume that the current in T_2 leads the current in T_1 by $\angle a$ degrees. Then, since the signal from T_1 must travel the added distance $kd \cos \phi$, expressed as an angular portion of a wavelength, the voltage vector of T_2 at point P will lead the voltage vector of T_1 by $a + kd \cos \phi$ degrees. (Fig. 2.) Regardless of the signs of $\angle a$ and of $kd \cos \phi$, the angle between the voltage vectors will be the algebraic sum. Positive values are used here merely for illustration.

As angle ϕ is varied from 0 to 360 degrees, that is, as point P is shifted around the antenna system, vector ET_2 may be conceived of as describing an oscillation

* Decimal classification: R325.1. Original manuscript received by the Institute, August 8, 1944.

† Federal Communications Commission, Dallas, Texas.

[1] Patent rights reserved.

[2] R. M. Foster, "Directive diagrams of antenna arrays," *Bell Sys. Tech. Jour.*, vol. 5, pp. 292–307; April, 1926.

[3] A. James Ebel, "Directional radiation patterns." *Electronics*, vol. 9, pp. 29–30; April, 1936.

[4] G. H. Brown, "Directional antennas," Proc. I.R.E., vol. 25, pp. 78–145; January, 1937.

about the end of vector ET_1. The center position of this oscillation, occurring at $\phi=90$ degrees and at $\phi=270$ degrees (i.e., $kd \cos \phi=0$) is determined by the phasing of the towers, while the magnitude of oscillation is determined by the spacing of the towers.[5] (Fig. 3). With vector ET_1 as reference, the length of ET_2 is determined by the ratio of the field of T_2 to the field of T_1.[6] Where the towers are of differing heights, the length of vector ET_2 is also adjusted to account for the differing effective fields. In this calculator, the tower producing the larger vector is taken as the reference (T_1), and the vector is assigned the value of one ($ET_1=1$).

The calculator provides a mechanical means of evaluating E_R, the resultant vector, at any value of ϕ for differing values of phasing ($\angle a$), spacing (kd), and field ratios (ET_2/ET_1). The way in which this is done may be seen by a study of Fig. 3. A device consisting essentially of a fixed vector, corresponding to ET_1, and a rotary

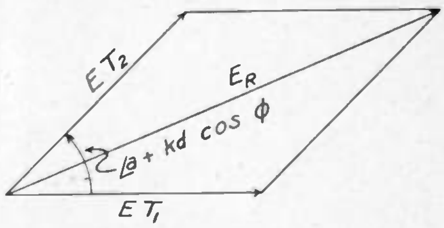


Fig. 2—Vector combination at point *P*.

vector, corresponding to ET_2, may be used to solve for E_R if scales are provided to measure the following:

1. Ratio of ET_2 to ET_1
2. Center position of ET_2 (i.e., the phasing angle of the current in T_2 with respect to the current in T_1)
3. Rotation of ET_2 from the center position as ϕ varies, for various values of spacing (kd), and
4. Values of E_R.

These are provided in the calculator. Angle ϕ is measured from the T_2 end of the line of towers, and since the pattern of a two-element array is symmetrical about the line of towers, it is necessary only to measure values of E_R for values of ϕ from 0 to 180 degrees.

Scale Calibration

In appearance and construction, the device is similar to a circular slide rule and consists of a fixed base and a rotary circular element, both bearing scales, and a transparent rotary calibrated runner. (Fig. 4.) The fixed base, containing the ϕ scales and loci of points of the kd scales, is laid out as follows:

A reference line is drawn upward from the pivot point of the rotary units. With the pivot point as a center, a series of circles and arcs is drawn whose radii correspond to various values of kd ranging from 360 to 45 degrees. Other values could be included, but it is thought that this range is representative of most arrays. The innermost circle is the one to contain ϕ scales for $kd=360$ degrees, and the intervals between succeeding circles and arcs correspond to decrements of 15 degrees in spacing, with two exceptions: Arcs are drawn for values of $kd=138$ degrees and $kd=316.5$ degrees. Spangenberg[7] has indicated that arrays with these spacings have cer-

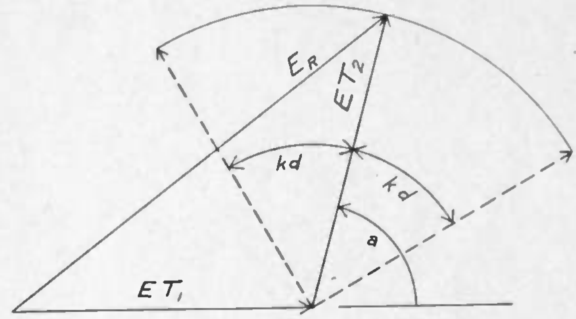


Fig. 3—Oscillation of vector ET_2 as angle ϕ is varied.

tain special characteristics, and scales are provided for these values for the purpose of allowing ready investigation of the patterns obtainable. The calibration marks on the runner allow values of spacing to be determined to 3 degrees.

The calibration mark for each value of ϕ on each arc or circle is determined as illustrated in Fig. 5. The arc contained between the calibration mark and the reference line subtends a central angle equal to $kd \cos \phi$. Thus the position of each calibration mark may be determined by measuring the central angle and projecting to the point of intersection on the circle or arc being scaled. Central angles for these scales are calculated by simple arithmetic, and results for the values selected are listed in Table I. Positive angles are measured counterclockwise from the reference line, and negative angles in a clockwise direction. Values for $\phi=90$ degrees fall along the reference line, and isometric lines are drawn through all other values of ϕ. These lines, when used in connection with the scale on the calibrated runner, allow the runner to be set to these values of ϕ for spacings intermediate of those represented by the circles and arcs.

On the perimeter of the rotary element is inscribed a protractor scale, calibrated from 0 to 180 degrees in both a negative direction (clockwise from 0 degrees) and a positive direction (counterclockwise from 0 degrees). This constitutes the phasing ($\angle a$) scale, which gives the phasing of T_2 with respect to T_1. In operation of this device, the phasing angle on this scale is set to the 90-degree line of the ϕ scales (the reference line), for at $\phi=90$ degrees, the angle between the vectors is equal to the phasing angle.

Located on this rotary element are resultant vector scales, in circular form, from which the value of E_R is

[5] F. Alton Everest and Wilson S. Pritchett, "Horizontal-polar-pattern tracer for directional broadcast antennas," Proc. I.R.E., vol. 30, pp. 227–232; May, 1942.

[6] John F. Morrison, "Simple method for observing current amplitude and phase relations in antenna arrays," Proc. I.R.E., vol. 25, pp. 1310–1326; October, 1937.

[7] Karl Spangenberg, "Charts for the determination of the root-mean-square value of the horizontal radiation pattern of two-element broadcast antenna arrays," Proc. I.R.E., vol. 30, pp. 237–240; May, 1942.

obtained, for ratios of ET_2/ET_1 ranging from 0.2 to 1.0 in steps of 0.1. Isometric lines are drawn through equal points on the E_R scales, so that by means of the calibrated runner, values of ET_2/ET_1 determined to 0.02 may be used.

This equation is placed in form (3) so that the results obtained may be most useful in plotting points along the E_R scales, for in this form, the values of $a+kd\cos\phi$ may be determined for desired decimal values of E_R. Where $ET_2/ET_1=1$, $(ET_2=ET_1=1)$, equation (3) becomes

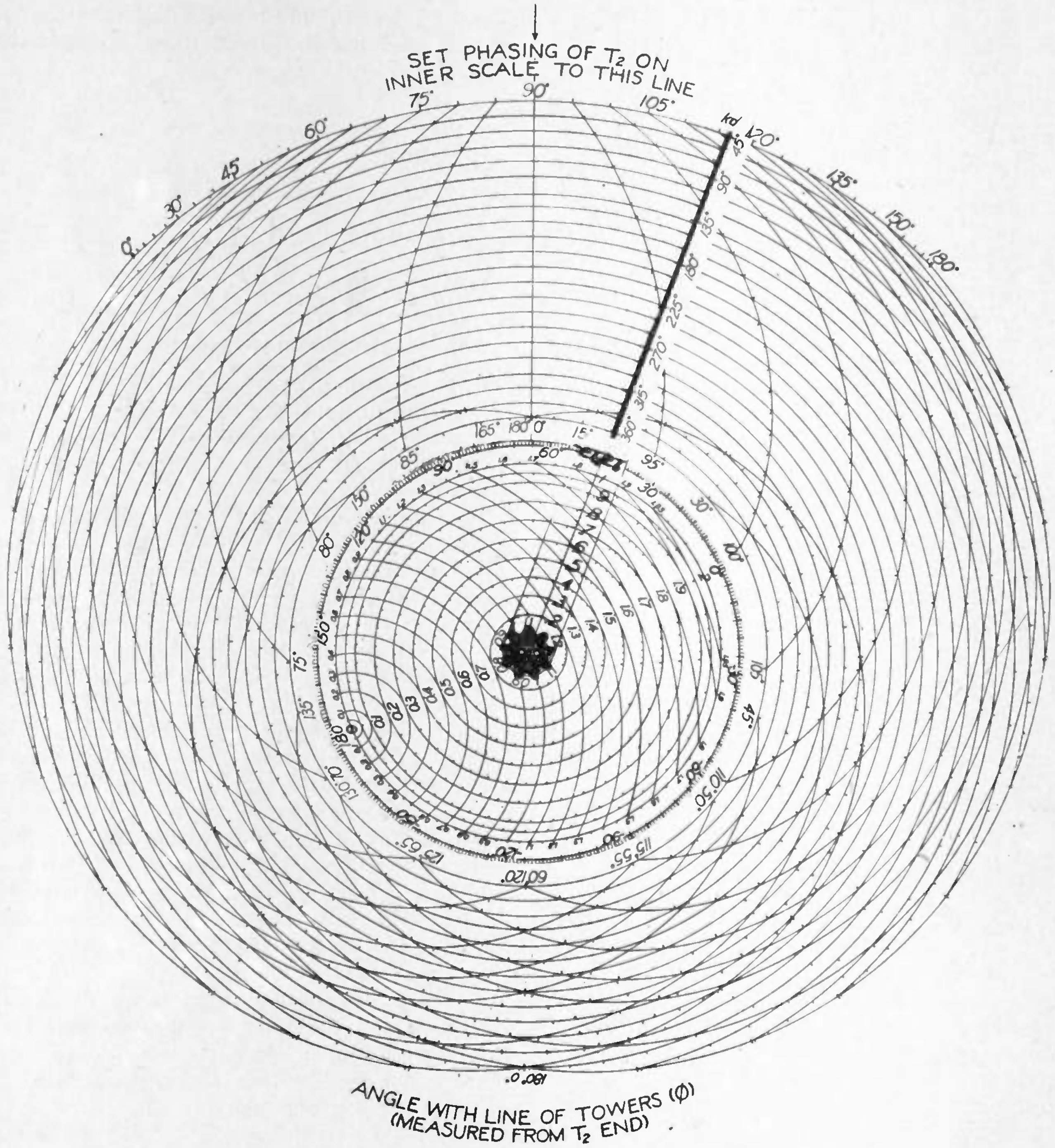


Fig. 4—The horizontal-pattern calculator for two-element directive arrays.

The E_R scales are computed trigonometrically, as illustrated in Fig. 6. Here, by the law of cosines:

$$E_R^2 = ET_1^2 + ET_2^2 - 2ET_1ET_2 \cos\left(180 \text{ degrees} - \overline{a + kd\cos\phi}\right) \quad (1)$$

$$E_R^2 = ET_1^2 + ET_2^2 + 2ET_1ET_2\cos(a + kd\cos\phi) \quad (2)$$

$$\cos(a + kd\cos\phi) = (E_R^2 - ET_1^2 - ET_2^2)/(2ET_1ET_2). \quad (3)$$

$$\cos\left(\overline{a + kd\cos\phi}/2\right) = E_R/2. \quad (4)$$

The results obtained for the values selected are listed in Tables II to XI. As in the case of the fixed base, each calibration mark is determined by measuring the central angle and projecting to the point of intersection on the circle being scaled. (Fig. 7.) This angle may be measured directly on the protractor scale along the edge of the

TABLE I

CENTRAL ANGLES FOR CALIBRATION OF ϕ SCALES

ϕ	*kd* cos ϕ					
	kd = 45 degrees	*kd* = 60 degrees	*kd* = 75 degrees	*kd* = 90 degrees	*kd* = 105 degrees	*kd* = 120 degrees
Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees
0	45.0000	60.0000	75.0000	90.0000	105.0000	120.0000
5	44.8286	59.7714	74.7143	89.6571	104.6000	119.5428
10	44.3165	59.0886	73.8608	88.6329	103.4051	118.1772
15	43.4669	57.9558	72.4448	86.9337	101.4227	115.9116
20	42.2861	56.3814	70.4768	84.5721	98.6675	112.7628
25	40.7840	54.3786	67.9533	81.5679	95.1626	108.7572
30	38.9714	51.9618	64.9523	77.9427	90.9332	103.9236
35	36.8618	49.1490	61.4363	73.7235	86.1108	98.2980
40	34.4718	45.9624	57.4530	68.9436	80.4342	91.9248
45	31.8200	42.4266	53.0333	63.6399	74.2466	84.8532
50	28.9256	38.5674	48.2093	57.8511	67.4930	77.1348
55	25.8110	34.4148	43.0185	51.6220	60.2259	68.8296
60	22.5000	30.0000	37.5000	45.0000	52.5000	60.0000
65	19.0179	25.3572	31.6965	38.0358	44.3751	50.7144
70	15.3909	20.5212	25.6515	30.7818	35.9121	41.0424
75	11.6469	15.5292	19.4115	23.2938	27.1761	31.0548
80	7.8143	10.4190	13.0238	15.6285	18.2333	20.8380
85	3.9222	5.2296	6.5370	7.8444	9.1518	10.4592
90	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
95	− 3.9222	− 5.2296	− 6.5370	− 7.8444	− 9.1518	− 10.4592
100	− 7.8143	− 10.4190	− 13.0238	− 15.6285	− 18.2333	− 20.8380
105	− 11.6469	− 15.5292	− 19.4115	− 23.2938	− 27.1761	− 31.0584
110	− 15.3909	− 20.5212	− 25.6515	− 30.7818	− 35.9121	− 41.0424
115	− 19.0179	− 25.3572	− 31.6965	− 38.0358	− 44.3751	− 50.7144
120	− 22.5000	− 30.0000	− 37.5000	− 45.0000	− 52.5000	− 60.0000
125	− 25.8110	− 34.4148	− 43.0185	− 51.6220	− 60.2259	− 68.8296
130	− 28.9256	− 38.5674	− 48.2093	− 57.8511	− 67.4930	− 77.1348
135	− 31.8200	− 42.4266	− 53.0333	− 63.6399	− 74.2466	− 84.8532
140	− 34.4718	− 45.9624	− 57.4530	− 68.9436	− 80.4342	− 91.9248
145	− 36.8618	− 49.1490	− 61.4363	− 73.7235	− 86.1108	− 98.2980
150	− 38.9714	− 51.9618	− 64.9523	− 77.9427	− 90.9332	−103.9236
155	− 40.7840	− 54.3786	− 67.9533	− 81.5679	− 95.1626	−108.7572
160	− 42.2861	− 56.3814	− 70.4768	− 84.5721	− 98.6675	−112.7628
165	− 43.4669	− 57.9558	− 72.4448	− 86.9337	−101.4227	−115.9116
170	− 44.3165	− 59.0886	− 73.8608	− 88.6329	−103.4051	−118.1772
175	− 44.8286	− 59.7714	− 74.7143	− 89.6571	−104.6000	−119.5428
180	− 45.0000	− 60.0000	− 75.0000	− 90.0000	−105.0000	−120.0000

ϕ	*kd* cos ϕ				
	kd = 225 degrees	*kd* = 240 degrees	*kd* = 255 degrees	*kd* = 270 degrees	*kd* = 285 degrees
Degrees	Degrees	Degrees	Degrees	Degrees	Degrees
0	225.0000	240.0000	255.0000	270.0000	285.0000
5	224.1428	239.0856	254.0285	268.9713	283.9142
10	221.5823	236.3544	251.1266	265.8987	280.6709
15	217.3343	231.8232	246.3122	260.7011	275.2901
20	211.4303	225.5256	239.6210	253.7163	267.8117
25	203.9198	217.5144	231.1091	244.7037	258.2982
30	194.8568	207.8472	220.8377	233.8281	246.8186
35	184.3088	196.5960	208.8833	221.1705	233.4578
40	172.3590	183.8496	195.3402	206.8308	218.3214
45	159.0998	169.7064	180.3131	190.9197	201.5264
50	144.6278	154.2696	163.9115	173.5533	183.1952
55	129.0555	137.6592	146.2629	154.8666	163.4703
60	112.5000	120.0000	127.5000	135.0000	142.5000
65	95.0895	101.4288	107.7681	114.1074	120.4467
70	76.9545	82.0848	87.2151	92.3454	97.4757
75	58.2345	62.1168	65.9991	69.8814	73.7637
80	39.0713	41.6760	44.2808	46.8855	49.4903
85	19.6110	20.9184	22.2258	23.5332	24.8406
90	0.0000	0.0000	0.0000	0.0000	0.0000
95	− 19.6110	− 20.9184	− 22.2258	− 23.5332	− 24.8406
100	− 39.0713	− 41.6760	− 44.2808	− 46.8855	− 49.4903
105	− 58.2345	− 62.1168	− 65.9991	− 69.8814	− 73.7637
110	− 76.9545	− 82.0848	− 87.2151	− 92.3454	− 97.4757
115	− 95.0895	−101.4288	−107.7681	−114.1074	−120.4467
120	−112.5000	−120.0000	−127.5000	−135.0000	−142.5000
125	−129.0555	−137.6592	−146.2629	−154.8666	−163.4703
130	−144.6278	−154.2696	−163.9115	−173.5533	−183.1952
135	−159.0998	−169.7064	−180.3131	−190.9197	−201.5264
140	−172.3590	−183.8496	−195.3402	−206.8308	−218.3214
145	−184.3088	−196.5960	−208.8833	−221.1705	−233.4578
150	−194.8568	−207.8472	−220.8377	−233.8281	−246.8186
155	−203.9198	−217.5144	−231.1091	−244.7037	−258.2982
160	−211.4303	−225.5256	−239.6210	−253.7163	−267.8117
165	−217.3343	−231.8232	−246.3122	−260.7011	−275.2901
170	−221.5823	−236.3544	−251.1266	−265.8987	−280.6709
175	−224.1428	−239.0856	−254.0285	−268.9713	−283.9142
180	−225.0000	−240.0000	−255.0000	−270.0000	−285.0000

ϕ	*kd* cos ϕ					
	kd = 138 degrees	*kd* = 150 degrees	*kd* = 165 degrees	*kd* = 180 degrees	*kd* = 195 degrees	*kd* = 210 degrees
Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees
0	138.0000	150.0000	165.0000	180.0000	195.0000	210.0000
5	137.4742	149.4285	164.3714	179.3142	194.2571	209.1999
10	135.9038	147.7215	162.4937	177.2658	192.0380	206.8101
15	133.2983	144.8895	159.3785	173.8674	188.3564	202.8453
20	129.6772	140.9535	155.0489	169.1442	183.2396	197.3349
25	125.0708	135.9465	149.5412	163.1358	176.7305	190.3251
30	119.5121	129.9045	142.8949	155.8854	168.8759	181.8663
35	113.0427	122.8725	135.1598	147.4470	159.7343	172.0215
40	105.7135	114.9060	126.3966	137.8872	149.3778	160.8684
45	97.5812	106.0665	116.6707	127.2798	137.8865	148.4931
50	88.7050	96.4185	106.0604	115.7022	125.3441	134.9859
55	79.1540	86.0370	94.6407	103.2444	111.8481	120.4518
60	69.0000	75.0000	82.5000	90.0000	97.5000	105.0000
65	58.3216	63.3930	69.7323	76.0716	82.4109	88.7502
70	47.1988	51.3030	56.4333	61.5636	66.6939	71.8242
75	35.7172	38.8230	42.7053	46.5876	50.4699	54.3522
80	23.9637	26.0475	28.6523	31.2570	33.8618	36.4665
85	12.0281	13.0740	14.3814	15.6888	16.9962	18.3036
90	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
95	− 12.0281	− 13.0740	− 14.3814	− 15.6888	− 16.9962	− 18.3036
100	− 23.9637	− 26.0475	− 28.6523	− 31.2570	− 33.8618	− 36.4665
105	− 35.7172	− 38.8230	− 42.7053	− 46.5876	− 50.4699	− 54.3522
110	− 47.1988	− 51.3030	− 56.4333	− 61.5636	− 66.6939	− 71.8242
115	− 58.3216	− 63.3930	− 69.7323	− 76.0716	− 82.4109	− 88.7502
120	− 69.0000	− 75.0000	− 82.5000	− 90.0000	− 97.5000	−105.0000
125	− 79.1540	− 86.0370	− 94.6407	−103.2444	−111.8481	−120.4518
130	− 88.7050	− 96.4185	−106.0604	−115.7022	−125.3441	−134.9859
135	− 97.5812	−106.0665	−116.6707	−127.2798	−137.8865	−148.4931
140	−105.7135	−114.9060	−126.3966	−137.8872	−149.3778	−160.8684
145	−113.0427	−122.8725	−135.1598	−147.4470	−159.7343	−172.0215
150	−119.5121	−129.9045	−142.8949	−155.8854	−168.8759	−181.8663
155	−125.0708	−135.9465	−149.5412	−163.1358	−176.7305	−190.3251
160	−129.6772	−140.9535	−155.0489	−169.1442	−183.2396	−197.3349
165	−133.2983	−144.8895	−159.3785	−173.8674	−188.3564	−202.8453
170	−135.9038	−147.7215	−162.4937	−177.2658	−192.0380	−206.8101
175	−137.4742	−149.4285	−164.3714	−179.3142	−194.2571	−209.1999
180	−138.0000	−150.0000	−165.0000	−180.0000	−195.0000	−210.0000

ϕ	*kd* cos ϕ				
	kd = 300 degrees	*kd* = 316.5 degrees	*kd* = 330 degrees	*kd* = 345 degrees	*kd* = 360 degrees
Degrees	Degrees	Degrees	Degrees	Degrees	Degrees
0	300.0000	316.5000	330.0000	345.0000	360.0000
5	298.8570	315.2941	328.7427	343.6856	358.6284
10	295.4430	311.6924	324.9873	339.7595	354.5316
15	289.7790	305.7168	318.7569	333.2459	347.7348
20	281.9070	297.4119	310.0977	324.1931	338.3884
25	271.8930	286.8471	299.0823	312.6770	326.2716
30	259.8090	274.0985	285.7899	298.7804	311.7708
35	245.7450	259.2610	270.3195	282.6068	294.8940
40	229.8120	242.4517	252.7932	264.2838	275.7744
45	212.1330	223.8003	233.3463	243.9530	254.5596
50	192.8370	203.4430	212.1207	221.7626	231.4044
55	172.0740	181.5381	189.2814	197.8851	206.4888
60	150.0000	158.2500	165.0000	172.5000	180.0000
65	126.7860	133.7592	139.4646	145.8039	152.1432
70	102.6060	108.2493	112.8666	117.9969	123.1272
75	77.6460	81.9165	85.4106	89.2929	93.1752
80	52.0950	54.9602	57.3045	59.9093	62.5140
85	26.1480	27.5861	28.7628	30.0702	31.3776
90	0.0000	0.0000	0.0000	0.0000	0.0000
95	− 26.1480	− 27.5861	− 28.7628	− 30.0702	− 31.3776
100	− 52.0950	− 54.9602	− 57.3045	− 59.9093	− 62.5140
105	− 77.6460	− 81.9165	− 85.4106	− 89.2929	− 93.1752
110	−102.6060	−108.2493	−112.8666	−117.9969	−123.1272
115	−126.7860	−133.7592	−139.4646	−145.8039	−152.1432
120	−150.0000	−158.2500	−165.0000	−172.5000	−180.0000
125	−172.0740	−181.5381	−189.2814	−197.8851	−206.4888
130	−192.8370	−203.4430	−212.1207	−221.7626	−231.4044
135	−212.1330	−223.8003	−233.3463	−243.9530	−254.5596
140	−229.8120	−242.4517	−252.7932	−264.2838	−275.7744
145	−245.7450	−259.2610	−270.3195	−282.6068	−294.8940
150	−259.8090	−274.0985	−285.7899	−298.7804	−311.7708
155	−271.8930	−286.8471	−299.0823	−312.6770	−326.2716
160	−281.9070	−297.4119	−310.0977	−324.1931	−338.3884
165	−289.7790	−305.7168	−318.7569	−333.2459	−347.7348
170	−295.4430	−311.6924	−324.9873	−339.7595	−354.5316
175	−298.8570	−315.2941	−328.7427	−343.6856	−358.6284
180	−300.0000	−316.5000	−330.0000	−345.0000	−360.0000

element ($\angle a$ scale). For this purpose, the term $kd \cos \phi$ and the sign of $\angle a$ have no significance and may be ignored.

This construction may be simplified if the circular resultant vector scales are drawn so that the inner scale, representing $ET_2/ET_1 = 0.2$, has a radius two units in length, and the succeeding scales, representing increments of 0.1, are drawn with radii successively one unit longer. Then the isometric lines representing equal values of E_R may be drawn as arcs having the point $E_R = 0$ as their center and having radii equal to the value of E_R, measured in the same units as ET_2/ET_1. The rotary element of Fig. 4 illustrates this construction.

The rotary runner, in the section covering the ϕ scales, is calibrated in steps of 3 degrees for values of *kd* between 45 and 360 degrees, and in the section covering the vector scales, it is calibrated in steps of 0.02 for values of E_2/ET_1 between 0.2 and 1.0. Referring to Figs. 3 and 4, vector ET_1 may be visualized as being located on the rotary element, with its origin at the value $E_R=0$ and its head at the pivot point of the element. Likewise, vector ET_2 may be visualized as having its origin at the pivot point of the rotary runner and as lying along the calibrated scale of the runner, with its head at a point determined by its relative magnitude.

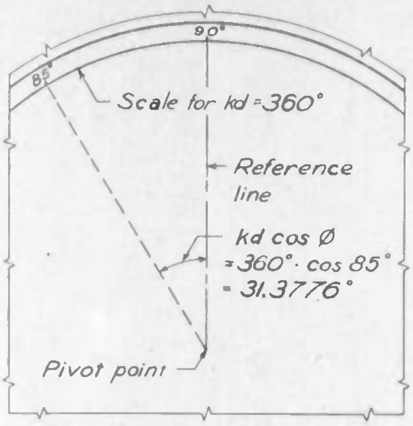


Fig. 5—Method of calibrating ϕ scales. Illustrated is the determination of the calibration point for $\phi=85$ degrees on the scale for $kd=360$ degrees.

In the construction of a calculator for an existing array, it is necessary to plot only one ϕ scale. If a change in frequency were contemplated, and it were desired that the existing tower arrangement be used, a new ϕ scale would have to be plotted for the changed value of electrical spacing (kd). Likewise, only that range of ET_2/ET_1 of interest to the station concerned need be plotted.

Operation

In operating this device to determine the horizontal field pattern of an array having known parameters, the towers are designated T_1 and T_2, with T_1 designating the tower producing the larger field-strength component, if they are unequal. The line of towers, T_1-T_2, is marked on polar graph paper, and angles of ϕ are measured from the T_2 end of this line. The phasing of T_2 on the $\angle a$ scale is set to the reference line, and the calibrated runner is moved to successive values of ϕ for the particular electrical spacing involved. At each value of ϕ, the value of E_R will be found on the vector scales under the calibration point on the runner corresponding to the ratio of ET_2/ET_1 being used. Plotting these values on the polar graph paper will give the horizontal pattern of the array.

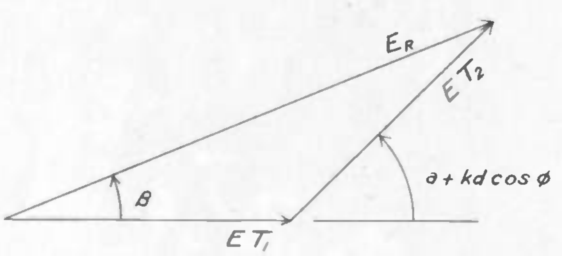


Fig. 6—Trigonometry of resultant vector-scale calculation.

In the determination of parameters for an array to fit a particular allocation problem, a value of kd may be selected and the runner set to the value of ϕ representing the direction in which the minimum signal is to be radiated. Move the rotary element to the point where $E_R=0$ is under the marker on the runner. Then the

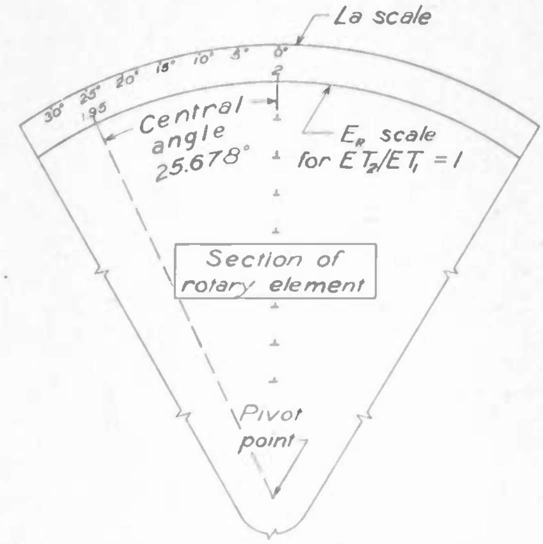


Fig. 7—Method of calibrating E_R scales. Illustrated is the determination of the calibration point for $E_R=1.95$ on the scale for $ET_2/ET_1=1$. The calibration mark designates the end of the arc which subtends the central angle determined from Table II. This angle may be measured on the $\angle a$ scale.

TABLE II

Central Angles for Calibration of E_R Scale When $ET_2/ET_1=1.00$

E_R	$a+kd\cos\phi$	E_R	$a+kd\cos\phi$
	Degrees		Degrees
2.00	0.000	1.05	116.668
1.99	11.466	1.00	120.000
1.98	16.265	0.95	123.281
1.97	19.872	0.90	126.512
1.96	22.955	0.85	129.699
1.95	25.678	0.80	132.843
1.90	36.388	0.75	135.952
1.85	44.667	0.70	139.024
1.80	51.683	0.65	142.069
1.75	57.908	0.60	145.083
1.70	63.578	0.55	148.077
1.65	68.823	0.50	151.044
1.60	73.738	0.45	153.995
1.55	78.388	0.40	156.925
1.50	82.819	0.35	159.842
1.45	87.062	0.30	162.747
1.40	91.147	0.25	165.638
1.35	95.093	0.20	168.521
1.30	98.916	0.15	171.340
1.25	102.635	0.10	174.266
1.20	106.261	0.05	177.145
1.15	109.801	0.00	180.000
1.10	113.266		

TABLE III

Central Angles for Calibration of E_R Scale When $ET_2/ET_1=0.95$
(5 Per Cent Unbalance of $ET_2/ET_1=1$)

E_R	$a+kd\cos\phi$	E_R	$a+kd\cos\phi$
	Degrees		Degrees
1.95	0.000	1.05	114.906
1.94	11.616	1.00	118.359
1.93	16.156	0.95	121.755
1.92	20.133	0.90	125.099
1.91	23.258	0.85	128.392
1.90	26.015	0.80	131.641
1.85	36.870	0.75	134.851
1.80	45.255	0.70	138.085
1.75	52.373	0.65	141.164
1.70	58.686	0.60	144.276
1.65	64.432	0.55	147.418
1.60	69.752	0.50	150.428
1.55	74.743	0.45	153.492
1.50	79.456	0.40	156.506
1.45	83.957	0.35	159.527
1.40	88.266	0.30	162.539
1.35	92.412	0.25	165.562
1.30	96.443	0.20	168.598
1.25	100.308	0.15	171.680
1.20	104.089	0.10	174.905
1.15	107.774	0.05	180.000
1.10	111.375		

TABLE IV

Central Angles for Calibration of E_R Scale When $ET_2/ET_1 = 0.9$

E_R	$a + kd \cos \phi$	E_R	$a + kd \cos \phi$
	Degrees		Degrees
1.90	0.000	1.05	113.144
1.89	11.780	1.00	116.745
1.88	16.665	0.95	120.276
1.87	20.419	0.90	123.749
1.86	23.589	0.85	127.169
1.85	26.389	0.80	130.542
1.80	37.398	0.75	133.872
1.75	45.906	0.70	137.167
1.70	53.130	0.65	140.429
1.65	59.540	0.60	143.669
1.60	65.376	0.55	146.877
1.55	70.782	0.50	150.073
1.50	75.863	0.45	153.260
1.45	80.647	0.40	156.444
1.40	85.220	0.35	159.634
1.35	89.603	0.30	162.854
1.30	93.822	0.25	166.126
1.25	97.903	0.20	169.523
1.20	101.862	0.15	173.242
1.15	105.714	0.10	180.000
1.10	109.471		

TABLE V

Central Angles for Calibration of E_R Scale When $ET_2/ET_1 = 0.8$

E_R	$a + kd \cos \phi$	E_R	$a + kd \cos \phi$
	Degrees		Degrees
1.80	0.000	1.05	109.487
1.79	12.167	1.00	113.584
1.78	17.200	0.95	117.450
1.77	21.083	0.90	121.200
1.76	24.355	0.85	124.990
1.75	27.250	0.80	128.683
1.70	38.550	0.75	132.300
1.65	47.383	0.70	135.952
1.60	54.933	0.65	139.550
1.55	61.566	0.60	143.133
1.50	67.600	0.55	146.667
1.45	73.200	0.50	150.233
1.40	78.466	0.45	153.833
1.35	83.450	0.40	157.667
1.30	88.150	0.35	161.458
1.25	92.775	0.30	165.466
1.20	97.183	0.25	170.584
1.15	101.433	0.20	180.000
1.10	105.575		

TABLE VI

Central Angles for Calibration of E_R Scale When $ET_2/ET_1 = 0.7$

E_R	$a + kd \cos \phi$	E_R	$a + kd \cos \phi$
	Degrees		Degrees
1.70	0.000	1.05	106.068
1.69	12.634	1.00	110.487
1.68	17.871	0.95	114.814
1.67	21.910	0.90	119.059
1.66	25.311	0.85	123.244
1.65	28.316	0.80	127.384
1.60	40.157	0.75	131.491
1.55	49.324	0.70	135.585
1.50	57.120	0.65	139.685
1.45	64.056	0.60	143.818
1.40	70.384	0.55	148.018
1.35	76.261	0.50	152.336
1.30	81.787	0.45	156.873
1.25	87.032	0.40	161.805
1.20	92.047	0.35	167.630
1.15	96.872	0.30	180.000
1.10	101.537		

TABLE VII

Central Angles for Calibration of E_R Scale When $ET_2/ET_1 = 0.6$

E_R	$a + kd \cos \phi$	E_R	$a + kd \cos \phi$
	Degrees		Degrees
1.60	0.000	1.00	107.458
1.59	13.242	0.95	112.411
1.58	18.736	0.90	117.279
1.57	22.964	0.85	122.090
1.56	26.533	0.80	126.870
1.55	29.686	0.75	131.650
1.50	42.126	0.70	136.497
1.45	51.760	0.65	141.392
1.40	60.000	0.60	146.443
1.35	67.330	0.55	151.793
1.30	74.038	0.50	157.667
1.25	80.285	0.45	164.705
1.20	86.177	0.40	180.000
1.15	91.790		
1.10	97.181		
1.05	102.391		

TABLE VIII TABLE IX

Central Angles for Calibration of E_R Scales When $ET_2/ET_1 = 0.5$ and 0.4, Respectively

E_R	$a + kd \cos \phi$	E_R	$a + kd \cos \phi$
	Degrees		Degrees
1.50	0.000	1.40	0.000
1.49	14.045	1.39	15.176
1.48	19.882	1.38	21.487
1.47	24.369	1.37	26.342
1.46	28.164	1.36	30.458
1.45	31.483	1.35	34.110
1.40	44.766	1.30	48.508
1.35	55.075	1.25	59.783
1.30	63.900	1.20	69.512
1.25	71.790	1.15	78.283
1.20	79.050	1.10	86.417
1.15	85.843	1.05	94.121
1.10	92.293	1.00	101.537
1.05	98.483	0.95	108.772
1.00	104.478	0.90	115.944
0.95	110.333	0.85	123.150
0.90	116.100	0.80	130.542
0.85	121.833	0.75	138.317
0.80	127.587	0.70	146.883
0.75	133.434	0.65	157.203
0.70	139.466	0.60	180.000
0.65	145.850		
0.60	152.873		
0.55	161.350		
0.50	180.000		

Table X TABLE XI

Central Angles for Calibration of E_R Scales When $ET_2/ET_1 = 0.3$ and 0.2, Respectively

E_R	$a + kd \cos \phi$	E_R	$a + kd \cos \phi$
	Degrees		Degrees
1.30	0.000	1.20	0.000
1.29	16.896	1.19	19.906
1.28	23.936	1.18	28.237
1.27	29.366	1.17	34.689
1.26	33.970	1.16	40.182
1.25	38.047	1.15	45.069
1.20	54.314	1.10	64.849
1.15	67.201	1.05	81.011
1.10	78.463	1.00	95.740
1.05	88.806	0.95	110.105
1.00	98.627	0.90	125.099
0.95	108.210	0.85	142.520
0.90	117.819	0.80	180.000
0.85	127.770		
0.80	138.590		
0.75	151.543		
0.70	180.000		

desired phasing of T_2 may be read from the $\angle a$ scale at the reference line. Repeating the process for other values of kd will enable one to obtain a group of patterns, with the parameters in each case, all producing a minimum signal in the desired direction in the horizontal plane. From these, the pattern to be used may be selected. Other procedures will suggest themselves to the experienced engineer.

It is, of course, important that the field radiated in the vertical plane also be considered in any allocation problem, and this must be taken into account with determinations obtained by the use of the calculator. Addition of scales necessary to accomplish this would unduly complicate the instrument; however, it is usually desired to determine the vertical pattern in only certain specific directions, and formulas for calculating the radiation are available from several sources.[4,8]

For values of kd between 180 and 360 degrees, two nulls may be obtained on each side of the line of towers. (Fig. 8.) The angles at which these nulls are obtained are labeled ϕ_1 and ϕ_2, with ϕ_1 the larger. In addition to being determined from the calculator, the parameters for an array having nulls at the desired values of ϕ_1 and ϕ_2 may be determined from the formulas:

[8] F. E. Terman, "Radio Engineers' Handbook," McGraw-Hill Book Company, New York 18, N. Y., 1943, p. 803.

$$kd = 360 \text{ degrees}/(\cos\phi_2 - \cos\phi_1) \quad (5)$$

$$\angle a = 180 \text{ degrees} - kd\cos\phi_2$$
$$= -180 \text{ degrees} - kd\cos\phi_1. \quad (6)$$

Application to More than Two Elements

With the use of a different type of resultant vector scale, the calculator may assist in determining the horizonal field pattern of an array consisting of more than two elements. An array of this type may be thought of

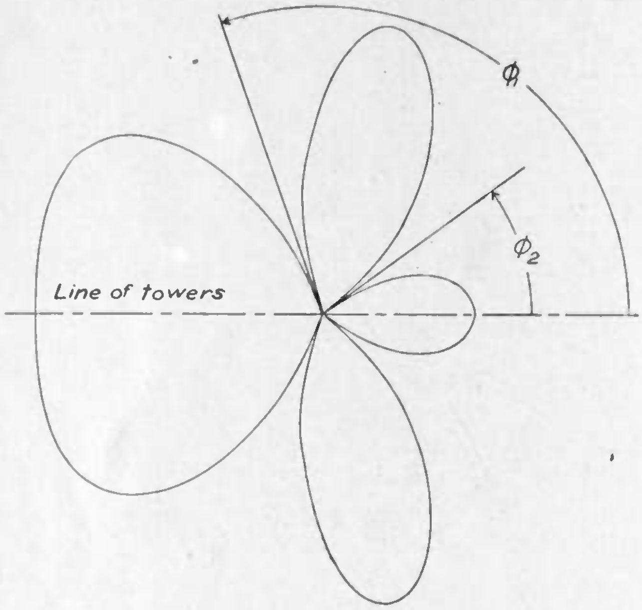


Fig. 8—Double nulls obtainable when 360 degrees > kd > 180 degrees, and $ET_3/ET_1 = 1$.

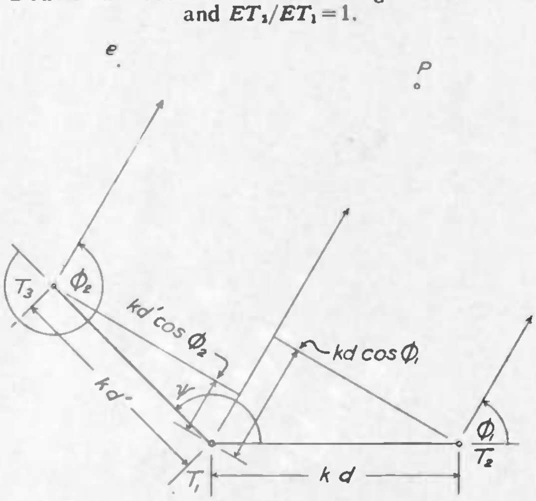


Fig. 9—Plan view of three-element array.

as a group of two-element arrays, with one element common to all such arrays. This common, or reference, element, labeled T_1, is the one producing the largest field component vector (ET_1). With a resultant scale calibrated to give the resultant vector E_R in rectangular co-ordinate form, $E_R \cos\beta \pm jE_R \sin\beta$ (where β is the angle between vectors ET_1 and E_R), a number of vectors occurring at any point in the field may readily be added.

Because the reference vector $ET_1(=1+j0)$ is common to all two-element arrays considered, it appears in the sum once too often for each such two-element array considered after the first. Hence, in determining the field strength at any point in the field of an array consisting of a total of N elements, $(N-2)ET_1(=N-2+j0)$ must be subtracted from the sum of the resultant vectors at that point.

Fig. 9 indicates a three-element array with the elements not in line, and Fig. 10 indicates the vector combinations resulting at point P. In using the calculator in this way, care must be taken that the lines of direction to point P coincide for the different two-element arrays. Thus, in Fig. 9, $\phi_2 = \phi_1 + 360 \text{ degrees} - \psi$. However, because a *two-element* array is symmetrical about the line of towers, ϕ_2 may also be taken equal to $\psi - \phi_1$.

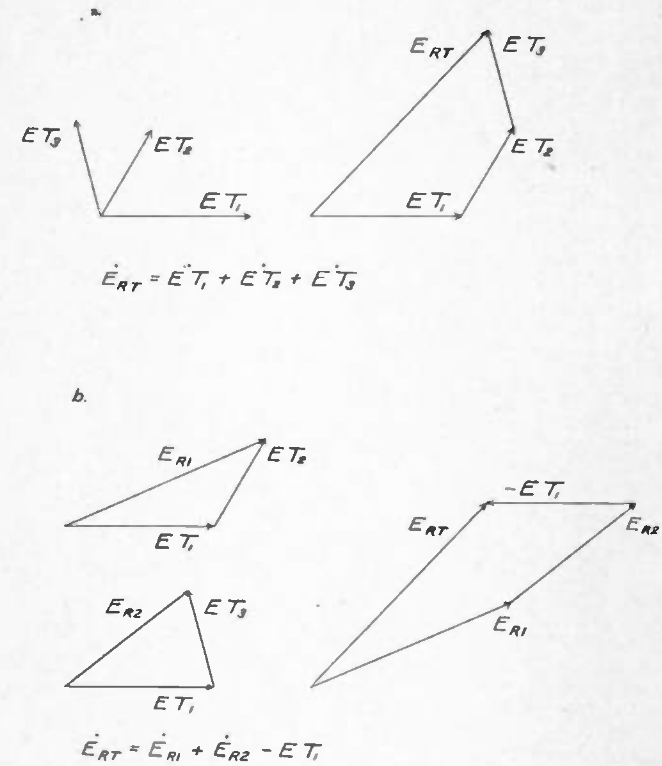


Fig. 10—Vector combination at point P of Fig. 9. a. Combination of three vectors directly; b. Combination of vectors when array is considered to consist of two two-element arrays, with T_1 common to both.

The necessity for providing two resultant scales instead of one would tend to make this portion of the calculator somewhat difficult to read, if resultants were scaled for a large number of values of ET_2/ET_1. In the supplementary rotary element illustrated in Fig. 11, only the values for $ET_2/ET_1 = 1$ are scaled. In a calculator designed for an existing array, it would be necessary to provide scales for only existing field ratios and the corresponding 5 per cent unbalance.

The scales may be calculated as follows: (Refer to Fig. 6.)

$$ET_1 = E_R\cos\beta + ET_2\cos(180 \text{ degrees} - \overline{a + kd\cos\phi}) \quad (7)$$

$$\cos(a + kd\cos\phi) = (E_R\cos\beta - ET_1)/ET_2 \quad (8)$$

and $ET_2/\sin\beta = E_R/[\sin(180 \text{ degrees} - \overline{a + kd\cos\phi})]$ (9)

$$\sin(a + kd\cos\phi) = (E_R\sin\beta)/ET_2. \quad (10)$$

When $ET_2 = ET_1 = 1$,

$$\cos(a + kd\cos\phi) = (E_R\cos\beta) - 1 \quad (11)$$

and $\sin(a+kd\cos\phi)=E_R\sin\beta.$ (12)

These formulas are most useful in the forms shown in (8) and (10), for in these forms, central angles $(a+kd\cos\phi)$ may readily be determined for desired decimal values of $E_R\cos\beta$ and $E_R\sin\beta$. Scales on this supplementary rotary element are calibrated in a manner similar to that described for the calibration of scales on the regular rotary element. Tables XII and XIII give the central angles used in calibrating the resultant scales illustrated in Fig. 11. The negative "j" terms are those

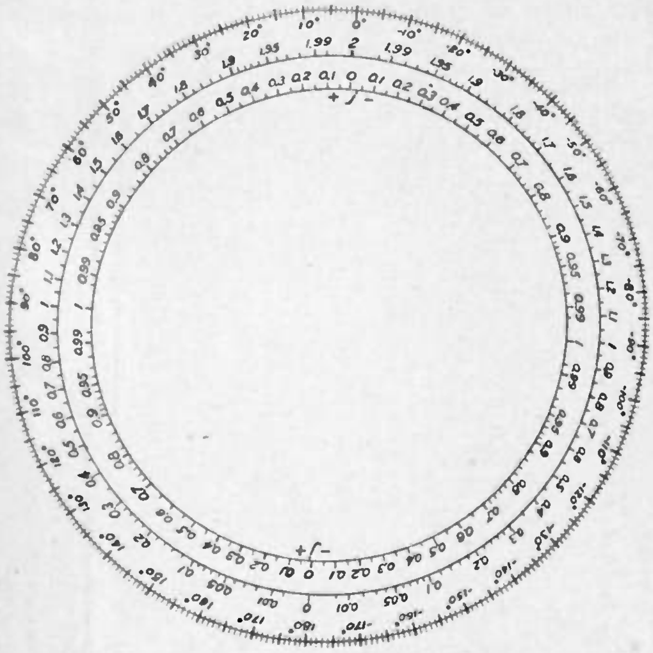


Fig. 11—Supplementary rotary element for use in calculating horizontal patterns of arrays consisting of more than two elements.

scaled in the two quadrants in which the phasing angles ($\angle a$ scale) are negative.

Accuracy and Limitations

The accuracy of this instrument will depend largely upon the care taken in its construction and operation. Generally, the larger the instrument, the greater will be the accuracy and ease of operation obtained. With a carefully constructed instrument of convenient size, an accuracy to three significant figures or better should be obtained.

As indicated, this calculator, in the form described, is limited to determination of the horizontal pattern and

TABLE XII

Central Angles for Calibration of Resultant Vector Scale in Rectangular Co-ordinate Form. Real Terms for $ET_1/ET_1=1$.

$E_R\cos\beta$	$a+kd\cos\phi$	$E_R\cos\beta$	$a+kd\cos\phi$	$E_R\cos\beta$	$a+kd\cos\phi$
	Degrees		Degrees		Degrees
2.00	0.000	1.55	56.633	0.35	130.541
1.995	5.734	1.50	60.000	0.30	134.427
1.99	8.108	1.45	63.256	0.28	136.054
1.98	11.478	1.40	66.422	0.26	137.732
1.97	14.069	1.35	69.509	0.24	139.464
1.96	16.260	1.30	72.542	0.22	141.261
1.95	18.194	1.25	75.523	0.20	143.130
1.94	19.948	1.20	78.463	0.18	145.084
1.93	21.565	1.15	81.373	0.16	147.140
1.92	23.074	1.10	84.261	0.14	149.316
1.91	24.495	1.05	87.135	0.12	151.642
1.90	25.842	1.00	90.000	0.10	154.158
1.88	28.358	0.95	92.865	0.09	155.505
1.86	30.684	0.90	95.739	0.08	156.926
1.84	32.860	0.85	98.627	0.07	158.435
1.82	34.916	0.80	101.537	0.06	160.052
1.80	36.870	0.75	104.477	0.05	161.806
1.78	38.739	0.70	107.458	0.04	163.740
1.76	40.536	0.65	110.491	0.03	165.931
1.74	42.268	0.60	113.578	0.02	168.522
1.72	43.946	0.55	116.744	0.01	171.892
1.70	45.573	0.50	120.000	0.005	174.266
1.65	49.459	0.45	123.367	0.000	180.000
1.60	53.130	0.40	126.870		

TABLE XIII

Central Angles for Calibration of Resultant Vector Scale in Rectangular Co-ordinate Form. J Terms for $ET_1/ET_1=1$.

$E_R\sin\beta$	$a+kd\cos\phi$		$E_R\sin\beta$	$a+kd\cos\phi$	
	Degrees	Degrees		Degrees	Degrees
0.00	0.000	180.000	0.78	51.261	128.739
0.05	2.865	177.135	0.80	53.130	126.870
0.10	5.739	174.261	0.82	55.084	124.916
0.15	8.627	171.373	0.84	57.140	122.860
0.20	11.537	168.463	0.86	59.316	120.684
0.25	14.477	165.523	0.88	61.642	118.358
0.30	17.458	162.542	0.90	64.158	115.842
0.35	20.491	159.509	0.91	65.505	114.495
0.40	23.578	156.422	0.92	66.926	113.074
0.45	26.744	153.256	0.93	68.435	111.565
0.50	30.000	150.000	0.94	70.052	109.948
0.55	33.367	146.633	0.95	71.806	108.194
0.60	36.870	143.130	0.96	73.740	106.260
0.65	40.541	139.459	0.97	75.931	104.069
0.70	44.427	135.573	0.98	78.522	101.478
0.72	46.054	133.946	0.99	81.892	98.108
0.74	47.732	132.268	0.995	84.266	95.734
0.76	49.464	130.536	1.000	90.000	90.000

gives no information regarding the vertical pattern. The instrument is not used by the Federal Communications Commission for allocation problems.

Acknowledgment

The author gratefully acknowledges comments made by Mr. C. M. Daniell, consulting radio engineer, regarding pattern calculators in general. Appreciation also is expressed for the assistance rendered by the author's colleagues in suggesting certain revisions in this article.

Institute of Radio Engineers to

The Board of Directors of the Institute has appointed a Building Fund Committee and will soon inaugurate a campaign to raise, among the members of the Institute, their well-wishers, and corporate friends, a sum of money "to be used in connection with the establishment of a suitable headquarters building, whether alone or in association with other engineering societies, as the opportunity presents." Further particulars will appear in subsequent issues of the PROCEEDINGS, and otherwise be brought to the attention of the membership.

The growth of membership, scope, and influence of the Institute warrants such a step at this time. From small beginnings, ours has become one of the major international engineering societies. It is in keeping with our present activities and attainments and our prospective needs and usefulness to the radio-and-electronic industries that we should be permanently housed.

The present membership of the Institute is over 12,000, representing almost 100% increase over that of 1940. From Fig. 1 which is reproduced with this article from the Report of the Secretary for 1943 and from a consideration of the history of the radio-and-electronic industries may be deduced the reasonable expectation that there will be rapid expansion with the advent of peace. There is reason to believe that electronics applications to industry after this war will reach something of the avalanche proportions of radio applications after World War I. The surrounding circumstances are the same: war-stimulated research, undercover infiltration of advanced technology waiting to burst its bonds, unsatisfied consumer demand, pent-up buying power, and a new generation of youthful enthusiasm and experience to be released from the Armed Services. The expansion of electronic controls and electronic power to industry can be clearly discerned; so can the expansion of television, frequency modulation, radar, wide-band coaxial cable and radio relay communication systems and other as yet undisclosed devices and fields. Hidden from all our plans, as the enormous radio broadcasting development of the '20's was hidden from the research engineers of the first World War, is the precise form that a parallel development may take in the late '40's and early '50's. That the development will come we may argue by analogy. That the activities of the Institute will be fundamentally necessary to it, this time as it was last, is no less certain.

If the Institute is to grow with the industry and the civilization it serves, it must promptly take on and meet the increased responsibilities which go with growth. With removal of paper restrictions and the release of military inhibitions on certain types of publication, the PROCEEDINGS will become more voluminous. As the field of electronic applications mushrooms out, our publication scope must and will widen to match it, for only by comprehensive publication service may the Institute expect to serve the whole radio-and-electronic field and remain a cohesive force in tying the myriad applications to fundamental scientific research and measurement. The Institute must also continue to serve the professional interests of its engineering members, to make its voice heard in standardization work, in government

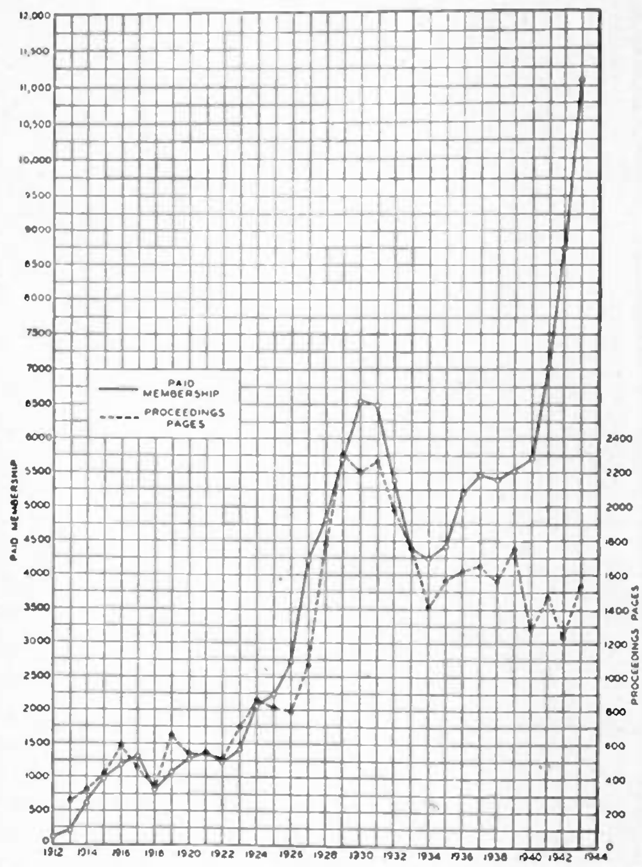


FIG. 1—The variation in paid membership is shown by the solid graph. The dotted line is for the number of pages of technical and editorial material in the PROCEEDINGS. Starting in 1939, a larger format was used and the scale of pages should be divided by 2.2.

counsel, in professional and labor circles. The future communication engineers and electronic engineers need their Institute.

All this, as a practical matter, translates in part into more staff and more office space. In the opinion of the Board of Directors, the half-way measure of hiring larger quarters is not the answer. The Institute should obtain in the near future a building, suited to the functional needs of the Institute, of a dignity in keeping with its prestige, and large enough for its prospective needs over a long period of years.

Act to Secure a Permanent Home

During the past year the Board has been active in visiting sites and investigating the possibilities, and is continuing its explorations. Although recognizing the tremendous advantage of being able to go before the membership and other prospective donors with a photograph or architectural drawing of the building which it might intend to purchase or erect, final determination of the course to be pursued has had to be left open for the unfolding of events. The present is considered a favorable time to secure funds, so much so that if the opportunity is allowed to pass, it may not occur again. In these circumstances, when the campaign is launched, it will have as an objective a sum which will afford leeway for making one of several different possible moves, including immediate occupancy of a permanent building; purchase of temporary quarters or rental looking forward to postwar ownership or erection of a permanent building; joining with the Founder Societies or with other engineering or scientific organizations in co-operative home ownership. Appropriate additional conditions will surround and safeguard the funds which are secured.

The following brief history of Institute quarters, culminating in the present crowded conditions, will give point to the needs:

When The Institute of Radio Engineers was founded on May 13, 1912, by the amalgamation of the Wireless Institute in New York City and the Society of Wireless Telegraph Engineers in Boston, its membership was less than fifty. It had no real office headquarters for many years, for its business was conducted from private offices at 71 Broadway and 111 Broadway, New York, until 1918, when Dr. Alfred N. Goldsmith, who carried the dual burden of Secretary and Editor, discharged these duties from his offices at the College of the City of New York.

In the spring of 1924 a small suite of offices was leased at 37 West 39th Street in New York City, and the Institute had its first real headquarters. The organization was growing in such a healthy manner that in January, 1927, it was necessary to employ a full-time Assistant Secretary and a small clerical staff to handle the volume of work. In the early winter of 1928, that space was outgrown, so larger and more spacious quarters were rented in the Engineering Societies Building at 33 West 39th Street. The staff again was enlarged and included a full-time Secretary, Assistant Secretary, Assistant Editor, Circulation Manager, Advertising Manager, and Head Bookkeeper. The space in the Engineering Societies Building was adequate for a few years, but in the spring of 1934 it was necessary to move again, this time to the McGraw-Hill Building at 330 West 42nd Street. In the winter of 1942, that suite proved to be too small and the Institute was moved, in the same building, to the larger but now inadequate quarters which it occupies at the present time.

Due to rapid growth of Institute activities, and even before expiration of the present favorable lease, we are faced with the problem of once more finding enough space to do our work. The Directors formerly had a crowded Board Room which it shared with Committees for their activities, including frequent meetings of the important Executive Committee, but that has been sacrificed to take care of the bookkeeping department, whose increase in work is roughly proportional to expanding membership. The Board and all the standing and technical committees now are forced to meet in rooms rented by the day, except when a small table in the Assistant Secretary's office will accommodate a few persons, to the detriment of our principal paid officer's work. The President has no office, nor has the Editor, the Secretary, or the Treasurer, even on a shared basis, in spite of their frequent and necessary visits to the office. The Advertising Manager, his office and staff, moved out of the suite some months ago to release needed space to others. The addressograph room is overcrowded. The files are split between the Institute office and other space some distance away. The Associate Editor and Office Manager have tiny cubicles, but the stenographic and clerical force are so badly cramped that carrying on special jobs like Radio Technical Planning Board co-operation, preparation of Yearbooks, and detail work of conventions severely cramps the staff. It must be borne in mind that when the several moves were made, prudent allowance was made for expansion, but the combination of numerical growth and broadening of scope of activity has far outrun all reasonable estimates.

The prospect of moving as often as in the past is unattractive. To acquire a really adequate floor area, such as there is in a building made to suit our functions, is so expensive as to indicate the advisability of purchasing.

The American Institute of Physics bought its own home about a year ago and has found it most satisfactory. The four Founder engineering societies, The American Institute of Electrical Engineers, American Society of Civil Engineers, American Society of Mechanical Engineers, and The American Society of Mining and Metallurgical Engineers have had their own home for about thirty years in the Engineering Societies Building and have found the co-operative arrangement well suited to their purposes. One or the other of these plans is within I.R.E.'s capacity to undertake, and, in the opinion of our Board, should be undertaken forthwith.

Institute News and Radio Notes

Board of Directors

October 4 Meeting: At the regular meeting of the Board of Directors, which was held on October 4, 1944, the following were present: H. M. Turner, president; R. A. Hackbusch, vice-president; S. L. Bailey, W. L. Barrow, E. F. Carter, I. S. Coggeshall, W. L. Everitt, Alfred N. Goldsmith, editor; R. A. Heising, treasurer; H. J. Reich, H. A. Wheeler, and W. B. Cowilich, assistant secretary.

Constitutional Amendments: The first ballot on Constitutional Amendments was mailed, in accordance with the recommendation of the Executive Committee, on September 15, 1944, to the entire voting membership. It is planned to mail another ballot, to be on the petitioned amendment of Article IV, after the results of the first ballot indicated become known.

The second ballot will contain a statement of H. P. Westman, from whom the petition had been received, and another statement signed by President Turner. A notice of the second ballot is also scheduled to appear in the December issue of the PROCEEDINGS.

Conferences

National Electronics Conference: A report on this conference was given by President Turner and followed by the discussion and actions indicated below:

Editor Goldsmith recommended that the Institute increase its support of this conference and pointed out that there is no duplication of interest or effort between the Institute's Electronics Conference, which is devoted primarily to theory, and the NEC. It was also suggested that the NEC could be expanded to be international in scope.

Broadcast Engineering Conference: It was the general opinion that a policy, similar to that outlined for the National Electronics Conference, would be desirable in case of the Broadcast Engineering Conference, of which the fifth and last meeting was held on February 23–27, 1942.

Canadian I.R.E. Council: These matters, concerning the Canadian membership of the Institute, were reported by Vice-President Hackbusch, and discussed and acted upon as shown below:

Canadian Radio Technical Planning Board: The progress of the CRTPB was described and it was proposed that the Institute consider making a contribution to the Canadian I.R.E. Council for the expense involved in carrying on the named Board's activities.

After discussing the Proposal, a suitable contribution was unanimously authorized, to be made through the Canadian I.R.E. Council, for the Canadian Radio Technical Planning Board work during the year beginning October, 1944.

Canadian Engineers' Council: It was stated that the Canadian Engineers' Council is in process of formation and would serve to represent the Canadian engineering and scientific bodies on matters relating to legislation, postwar planning, collective bargaining, and the Wartime Bureau of Technical Personnel in the Dominion.

Proceedings

Papers Procurement: Editor Goldsmith was authorized to send a double postal card to all members including Students, for the purpose of determining the papers that could be submitted now or in the near future, and those soon after the end of the war.

Papers Procurement Committee: The appointment of V. J. Young to the Timers and Technical Controls Group was unanimously approved.

Postwar Publication Fund: On recommendation of the Executive Committee, unanimous approval was given to increasing the reserve fund for postwar publications from $14,000 to $20,000 and to depositing the fund in a separate account as suggested by the auditor.

Tutorial Papers: The resumption of tutorial papers' was suggested and it was noted that a number of members are in favor of having the PROCEEDINGS publish good papers of this type. The following motion resulted from the discussion:

> "The Board is sympathetic to having the PROCEEDINGS publish outstanding tutorial papers whose presentation quality exceeds that of the average original papers."

1945 Winter Technical Meeting: In behalf of the Executive Committee, Mr. Wheeler reviewed the budget, program, and personnel of the General Committee for this meeting, which is scheduled to be held on January 24–27, 1945, at the Hotel Commodore, in New York.

The WTM activities, recommended in the September 28, 1944, letter from Austin Bailey, chairman of the WTM General Committee, were approved.

Annual Meeting: Upon the recommendation of the Executive Committee, it was decided to hold the Annual Meeting of the Institute during the half-hour interval between 10:00–10:30 A.M. on January 25, 1945, and as part of the 1945 Winter Technical activities at the Hotel Commodore, New York City.

Indianapolis Section: Mr. Wheeler reported on the request of the Indianapolis Section, made in the September 25, 1944, letter from Section Chairman H. I. Metz, for permission to affiliate with the Indianapolis Technical Societies Council. The constitution of the Council was discussed and it was noted that no dues are required of the member societies.

The motion, granting permission to the Indianapolis Section to become affiliated with the named Council, was approved by an unanimous vote.

Radio Technical Planning Board: In behalf of Secretary Pratt, the Institute's Representative on the RTPB, Dr. Barrow, as Alternate, reviewed briefly the meetings of the RTPB and its Administrative Committee which were held in September. These matters were discussed and it was decided that the Institute continue its support of the RTPB.

ASA Committee on Radio Noise: Mr. Wheeler, chairman of the Standards Committee, reported on the proposed ASA War Standards Committee on Methods of Measuring Radio Noise, which is in the process of organization.

After a discussion, the following members were appointed to the committee in the capacities indicated:

H. B. Fischer, Representative
C. J. Franks, Alternate
Garrard Mountjoy, Alternate

Executive Committee

October 3 Meeting: The following members were present at the October 3, 1944, meeting of the Executive Committee: H. M. Turner, president; E. F. Carter, Alfred N. Goldsmith, editor; R. A. Heising, treasurer; F. B. Llewellyn, H. A. Wheeler, and W. B. Cowilich, assistant secretary.

Membership: The following applications for membership were approved: for transfer to Senior Member grade, N. G. Anton, R. E. Beam, P. S. Christaldi, C. W. Corbett, L. T. DeVore, W. E. Donovan, F. A. Everest, D. G. Grieg, Samuel Gubin, K. G. MacLean, D. E. Noble, E. M. Ostlund, Simon Ramo, G. H. Scheer, Jr., J. F. Wentz, and J. W. Wright; for admission to Senior Member grade, V. W. Sherman, and O. S. Duffendack; for transfer to Member grade, M. E. Campbell, F. M. Deerhake, H. H. Edwards, H. E. Ellithorn, W. D. Espy, Manuel Fernandes, Leroy Fiedler, D. P. Gorman, A. W. Graf, O. C. Hirsch, H. S. McCartney, W. O. Sharp, P. W. Sokoloff, E. G. Squires, Harry Stockman, H. P. Thomas, T. S. Wang, and R. H. Williamson; for admission to Member grade, R. C. Curtis, F. M. Davis, Rudolf Feldt, A. H. Hackett, W. A. Laning, S. W. Norman, A. W. Warner, Jr., A. C. Weid, and Saul Weissman; Associate grade, 111; and Student grade, 30.

Petitioned Constitutional Amendment: Chairman Heising, as Constitution and Laws Committee Chairman, called attention to several matters relating to the petitioned amendment of Article IV, mentioned below:

Petition to Amend Article IV. These matters have been scheduled with reference to a separate ballot on the petitioned constitutional amendment:

(1) A separate ballot to be sent after the returns from the first constitutional-amendment ballot, mailed on September 14, 1944, have become known.

(2) A notice of the additional constitutional-amendment ballot to be published in the December issue of the PROCEEDINGS.

(3) The ballot on the petitioned

amendment to include a statement from H. P. Westman, from whom the petition had been received, and another statement signed by President Turner.

National Electronics Conference: The plan[illegible] his conference, scheduled to be held [illegible]th at Chicago, were considered to b[illegible]ressing favorably and it was stated th[illegible] many Institute members are planning to attend.

The suggestion was made to Mr. Wheeler that steps be taken to encourage the continuation of this conference, of which the Insti[illegible] Chicago Section is one of the spon[illegible]

Aud[illegible] Bure[illegible]u of Circulations: The circulation state[illegible]nents for the PROCEEDINGS covering the first six months of 1944, recently prepared and submitted by the Institute office, has been officially released by the A.B.C. Attention was called to monthly-aver[illegible]es, indicated below:

	January-June 1944	July-December 1943	January-June 1943
Total Distributions	13,348	11,754	10,427
Paid Memberships (excluding Students)	9,640	8,276	7,443
Paid Students	2,259	2,101	1,543
Paid [illegible] ti[illegible]	1,076	1,039	900

Ottawa Section: Mr. Wheeler reported that the Montreal Sections had agreed on the territory of the Ottawa Section, outlined below:

Co[illegible] in Or[illegible]ario: Lennox and Addington, [illegible], L[illegible]nark, Frontenac, Leeds, Carle[illegible] [illegible]renville, Dundas, Stormont, Glengary, Prescott, and Russell.

Electoral Districts in Province of Quebec: Pontiac, Hull, and Laval (Labelle).

It was further stated that the decision of the Montreal and Toronto Sections on the de[illegible] area, including proposals of the three [illegible] involved, had been communica[illegible] to the Ottawa Section, and that the reply of the latter Section is expected in the near future.

Technical Committees: Dr. Llewellyn pointed out that the technical committees are becoming more active and that consequently the need now exists for a full-time technical secretary to co-ordinate the work of these groups as had been done previously.

After a favorable discussion, it was decided to defer further consideration of the matter to the next meeting.

Propagation Data: In his capacity on the Executive Committee, Dr. Llewellyn called attention to a September 26, 1944, letter from W. R. G. Baker suggesting that the Institute co-ordinate available propagation data above 300 megacycles and release the information to the profession and to industry.

As a result of the discussion, it was moved to refer Dr. Baker's letter to Chairman C. R. Burrows of the Radio Wave Propagation Committee, with the sugges-tion that the committee take the action proposed by [illegible]paring a report and/or by having suita[illegible] papers submitted for publication in the [illegible]OCEEDINGS.

Subscripti[illegible]s: It was the opinion that the subscript[illegible] data on the *Journal of the Institution o[illegible] [illegible]ectrical Engineers* (England) should be p[illegible]icized in the PROCEEDINGS each month [illegible] year, that such information should inclu[illegible] the regular rates, and that those interes[illegible] should be directed to make their remitta[illegible]es to the London address of that journal.

It was fu[illegible]her decided to submit subscription dat[illegible]on the PROCEEDINGS for publication in th[illegible] *Journal of the I.E.E.* on a similar basis.

The Assi[illegible]nt Secretary was instructed to send the P[illegible]CEEDINGS data to Mr. W. K. Brasher, Secr[illegible]ary of the I.E.E. and to request similar [illegible]ta on their journal for use in the PROCEEDI[illegible]S.

Consti[illegible]utional-Amen[illegible]ment Section

By the ti[illegible] this issue of the PROCEEDINGS reach[illegible] [illegible]e membership, the ballots on the Consti[illegible]nal Amendments sent out in Septemb[illegible] w[illegible] have been counted. The result of the ba[illegible]t will appear in the January issue.

In the me[illegible] time, plans are under way to submit to a v[illegible] the proposed Constitutional Amendm[illegible] [illegible]bmitted by petition in August by Mr. [illegible]estman and other members. The voting [illegible]mbership may expect to receive their ba[illegible]ts on this amendment a short time after th[illegible]ppearance of this notice.

As stated [illegible]n earlier issues of the PROCEEDINGS the [illegible]m of these amendments is to establish a sy[illegible]em of dues that will facilitate the clas[illegible]on of members into grades commensura[illegible] with their qualifications without imp[illegible]ing a financial obligation which at pre[illegible]nt is regarded by some as a serious dete[illegible]nt to proper classification. Discussions [illegible] he proposed amendment will be transmitt[illegible] to the voting membership alon[illegible] wi[illegible] th[illegible]ballot. In the meantime, those interested wi[illegible] find the subject presented in the followin[illegible] [illegible]sues of the PROCEEDINGS:

Septemb[illegible] 1944, p. 567, letter from Mr. Westm[illegible]; also p. 562 paragraph No. 10;

Octobe[illegible], [illegible]44, p. 639; November, 1944, p. 71[illegible] [illegible]der Board of Directors.

R. A. HEISING, *Chairman*
Con[illegible]tution and Laws Committee

1945 [illegible]inter Techn[illegible]cal Meeting

Early re[illegible]nse from the radio engineers and indust[illegible] confirms the belief of the general com[illegible]tee in charge of the coming Winter Tech[illegible]cal Meeting that attendance at the four[illegible]y sessions, January 24–27, will reach a [illegible]w high in I.R.E history.

Many pr[illegible]lems must be met and solved by the vari[illegible]s subcommittees because of wartime con[illegible]ions but none is more critical than that o[illegible] hotel reservations for out-of-town guests. [illegible]Vith the opening date only a [illegible]

[illegible]

[illegible] time for last-[illegible]

It has alread[illegible] special sessions [illegible] industrial-electron[illegible] vances in vacuum-[illegible] ment, and to radio lin[illegible] ter subject is a parti[illegible] with television and [illegible] occupying the thought[illegible] on mass communication[illegible]

From all indications [illegible] one of the most importa[illegible] Winter Technical Meetin[illegible] firms that already have [illegible] space is so much greater tha[illegible] first estimated that addition[illegible] sought on the [illegible] it is hoped that [illegible] war devices will be [illegible] permit the exhibition of [illegible]ment.

As explained in the Nove[illegible] [illegible]CEEDINGS the general committee [illegible]nized the desire of [illegible] social meetings between [illegible] tail party" on the evening of [illegible] only one of the social high [illegible] arrangements will be made [illegible] ladies who come to New York for the [illegible]ing. Details of these attractions should be completed in time for an announcement in the January issue.

National Electronics Conference

Attracted by a program of fifty outstanding technical papers on all branches of technical developments in electronics, 2191 engineers, scientists, and technical workers were officially registered and took part in the technical meeting, banquet, and luncheons of the first National Electronics Conference at the Medinah Club of Chicago on October 5, 6, and 7. While the majority of those attending the Conference were from the United States, representatives from government or commercial agencies of Argentina, Canada, China, England, France, Mexico, and Russia were also present. The most prominent Canadian representative was Ralph A. Hackbusch, vice-president of

[illegible]rom 1934 to 19[illegible] Mr. Malling was en[illegible] in television [illegible]rch with the Baird [illegible]on Compan[illegible] England. In 1938 [illegible] in [illegible] television research

Institute News and Radio Notes

Board of Directors

October 4 Meeting: At the regular meeting of the Board of Directors, which was held on October 4, 1944, the following were present: H. M. Turner, president; R. A. Hackbusch, vice-president; S. L. Bailey, W. L. Barrow, E. F. Carter, I. S. Coggeshall, W. L. Everitt, Alfred N. Goldsmith, editor; R. A. Heising, treasurer; H. J. Reich, H. A. Wheeler, and W. B. Cowilich, assistant secretary.

Constitutional Amendments: The first ballot on Constitutional Amendments was mailed, in accordance with the recommendation of the Executive Committee, on September 15, 1944, to the entire voting membership. It is planned to mail another ballot, to be on the petitioned amendment of Article IV, after the results of the first ballot indicated become known.

The second ballot will contain a statement of H. P. Westman, from whom the petition had been received, and another statement signed by President Turner. A notice of the second ballot is also scheduled to appear in the December issue of the PROCEEDINGS.

Conferences

National Electronics Conference: A report on this conference was given by President Turner and followed by the discussion and actions indicated below:

Editor Goldsmith recommended that the Institute increase its support of this conference and pointed out that there is no duplication of interest or effort between the Institute's Electronics Conference, which is devoted primarily to theory, and the NEC. It was also suggested that the NEC could be expanded to be international in scope.

Broadcast Engineering Conference: It was the general opinion that a policy, similar to that outlined for the National Electronics Conference, would be desirable in case of the Broadcast Engineering Conference, of which the fifth and last meeting was held on February 23–27, 1942.

Canadian I.R.E. Council: These matters, concerning the Canadian membership of the Institute, were reported by Vice-President Hackbusch, and discussed and acted upon as shown below:

Canadian Radio Technical Planning Board: The progress of the CRTPB was described and it was proposed that the Institute consider making a contribution to the Canadian I.R.E. Council for the expense involved in carrying on the named Board's activities.

After discussing the Proposal, a suitable contribution was unanimously authorized, to be made through the Canadian I.R.E. Council, for the Canadian Radio Technical Planning Board work during the year beginning October, 1944.

Canadian Engineers' Council: It was stated that the Canadian Engineers' Council is in process of formation and would serve to represent the Canadian engineering and scientific bodies on matters relating to legislation, postwar planning, collective bargaining, and the Wartime Bureau of Technical Personnel in the Dominion.

Proceedings

Papers Procurement: Editor Goldsmith was authorized to send a double postal card to all members including Students, for the purpose of determining the papers that could be submitted now or in the near future, and those soon after the end of the war.

Papers Procurement Committee: The appointment of V. J. Young to the Timers and Technical Controls Group was unanimously approved.

Postwar Publication Fund: On recommendation of the Executive Committee, unanimous approval was given to increasing the reserve fund for postwar publications from $14,000 to $20,000 and to depositing the fund in a separate account as suggested by the auditor.

Tutorial Papers: The resumption of tutorial papers was suggested and it was noted that a number of members are in favor of having the PROCEEDINGS publish good papers of this type. The following motion resulted from the discussion:

> "The Board is sympathetic to having the PROCEEDINGS publish outstanding tutorial papers whose presentation quality exceeds that of the average original papers."

1945 Winter Technical Meeting: In behalf of the Executive Committee, Mr. Wheeler reviewed the budget, program, and personnel of the General Committee for this meeting, which is scheduled to be held on January 24–27, 1945, at the Hotel Commodore, in New York.

The WTM activities, recommended in the September 28, 1944, letter from Austin Bailey, chairman of the WTM General Committee, were approved.

Annual Meeting: Upon the recommendation of the Executive Committee, it was decided to hold the Annual Meeting of the Institute during the half-hour interval between 10:00–10:30 A.M. on January 25, 1945, and as part of the 1945 Winter Technical activities at the Hotel Commodore, New York City.

Indianapolis Section: Mr. Wheeler reported on the request of the Indianapolis Section, made in the September 25, 1944, letter from Section Chairman H. I. Metz, for permission to affiliate with the Indianapolis Technical Societies Council. The constitution of the Council was discussed and it was noted that no dues are required of the member societies.

The motion, granting permission to the Indianapolis Section to become affiliated with the named Council, was approved by an unanimous vote.

Radio Technical Planning Board: In behalf of Secretary Pratt, the Institute's Representative on the RTPB, Dr. Barrow, as Alternate, reviewed briefly the meetings of the RTPB and its Administrative Committee which were held in September. These matters were discussed and it was decided that the Institute continue its support of the RTPB.

ASA Committee on Radio Noise: Mr. Wheeler, chairman of the Standards Committee, reported on the proposed ASA War Standards Committee on Methods of Measuring Radio Noise, which is in the process of organization.

After a discussion, the following members were appointed to the committee in the capacities indicated:

H. B. Fischer, Representative
C. J. Franks, Alternate
Garrard Mountjoy, Alternate

Executive Committee

October 3 Meeting: The following members were present at the October 3, 1944, meeting of the Executive Committee: H. M. Turner, president; E. F. Carter, Alfred N. Goldsmith, editor; R. A. Heising, treasurer; F. B. Llewellyn, H. A. Wheeler, and W. B. Cowilich, assistant secretary.

Membership: The following applications for membership were approved: for transfer to Senior Member grade, N. G. Anton, R. E. Beam, P. S. Christaldi, C. W. Corbett, L. T. DeVore, W. E. Donovan, F. A. Everest, D. G. Grieg, Samuel Gubin, K. G. MacLean, D. E. Noble, E. M. Ostlund, Simon Ramo, G. H. Scheer, Jr., J. F. Wentz, and J. W. Wright; for admission to Senior Member grade, V. W. Sherman, and O. S. Duffendack; for transfer to Member grade, M. E. Campbell, F. M. Deerhake, H. H. Edwards, H. E. Ellithorn, W. D. Espy, Manuel Fernandes, Leroy Fiedler, D. P. Gorman, A. W. Graf, O. C. Hirsch, H. S. McCartney, W. O. Sharp, P. W. Sokoloff, E. G. Squires, Harry Stockman, H. P. Thomas, T. S. Wang, and R. H. Williamson; for admission to Member grade, R. C. Curtis, F. M. Davis, Rudolf Feldt, A. H. Hackett, W. A. Laning, S. W. Norman, A. W. Warner, Jr., A. C. Weid, and Saul Weissman; Associate grade, 111; and Student grade, 30.

Petitioned Constitutional Amendment: Chairman Heising, as Constitution and Laws Committee Chairman, called attention to several matters relating to the petitioned amendment of Article IV, mentioned below:

Petition to Amend Article IV. These matters have been scheduled with reference to a separate ballot on the petitioned constitutional amendment:

(1) A separate ballot to be sent after the returns from the first constitutional-amendment ballot, mailed on September 14, 1944, have become known.
(2) A notice of the additional constitutional-amendment ballot to be published in the December issue of the PROCEEDINGS.
(3) The ballot on the petitioned

amendment to include a statement from H. P. Westman, from whom the petition had been received, and another statement signed by President Turner.

National Electronics Conference: The plans for this conference, scheduled to be held this month at Chicago, were considered to be progressing favorably and it was stated that many Institute members are planning to attend.

The suggestion was made to Mr. Wheeler that steps be taken to encourage the continuation of this conference, of which the Institute's Chicago Section is one of the sponsors.

Audit Bureau of Circulations: The circulation statements for the PROCEEDINGS covering the first six months of 1944, recently prepared and submitted by the Institute office, has been officially released by the A.B.C. Attention was called to monthly-average increases, indicated below:

	January-June 1944	July-December 1943	January-June 1943
Total Distributions	13,348	11,754	10,427
Paid Memberships (excluding Students)	9,640	8,276	7,443
Paid Students	2,259	2,101	1,543
Paid Subscriptions	1,076	1,039	900

Ottawa Section: Mr. Wheeler reported that the Montreal Sections had agreed on the territory of the Ottawa Section, outlined below:

Counties in Ontario: Lennox and Addington, Renfrew, Lanark, Frontenac, Leeds, Carleton, Grenville, Dundas, Stormont, Glengary, Prescott, and Russell.

Electoral Districts in Province of Quebec: Pontiac, Hull, and Laval (Labelle).

It was further stated that the decision of the Montreal and Toronto Sections on the defined area, including proposals of the three Sections involved, had been communicated to the Ottawa Section, and that the reply of the latter Section is expected in the near future.

Technical Committees: Dr. Llewellyn pointed out that the technical committees are becoming more active and that consequently the need now exists for a full-time technical secretary to co-ordinate the work of these groups as had been done previously.

After a favorable discussion, it was decided to defer further consideration of the matter to the next meeting.

Propagation Data: In his capacity on the Executive Committee, Dr. Llewellyn called attention to a September 26, 1944, letter from W. R. G. Baker suggesting that the Institute co-ordinate available propagation data above 300 megacycles and release the information to the profession and to industry.

As a result of the discussion, it was moved to refer Dr. Baker's letter to Chairman C. R. Burrows of the Radio Wave Propagation Committee, with the suggestion that the committee take the action proposed by preparing a report and/or by having suitable papers submitted for publication in the PROCEEDINGS.

Subscriptions: It was the opinion that the subscription data on the *Journal of the Institution of Electrical Engineers* (England) should be publicized in the PROCEEDINGS each month for a year, that such information should include the regular rates, and that those interested should be directed to make their remittances to the London address of that journal.

It was further decided to submit subscription data on the PROCEEDINGS for publication in the *Journal of the I.E.E.* on a similar basis.

The Assistant Secretary was instructed to send the PROCEEDINGS data to Mr. W. K. Brasher, Secretary of the I.E.E. and to request similar data on their journal for use in the PROCEEDINGS.

Constitutional-Amendment Section

By the time this issue of the PROCEEDINGS reaches the membership, the ballots on the Constitutional Amendments sent out in September will have been counted. The result of the ballot will appear in the January issue.

In the meantime, plans are under way to submit to a vote the proposed Constitutional Amendment submitted by petition in August by Mr. Westman and other members. The voting membership may expect to receive their ballots on this amendment a short time after the appearance of this notice.

As stated in earlier issues of the PROCEEDINGS the aim of these amendments is to establish a system of dues that will facilitate the classification of members into grades commensurate with their qualifications without imposing a financial obligation which at present is regarded by some as a serious deterrent to proper classification. Discussions of the proposed amendment will be transmitted to the voting membership along with the ballot. In the meantime, those interested will find the subject presented in the following issues of the PROCEEDINGS:

September, 1944, p. 567, letter from Mr. Westman; also p. 562 paragraph No. 10;

October, 1944, p. 639; November, 1944, p. 713 under Board of Directors.

R. A. HEISING, *Chairman*
Constitution and Laws Committee

1945 Winter Technical Meeting

Early response from the radio engineers and industry confirms the belief of the general committee in charge of the coming Winter Technical Meeting that attendance at the four-day sessions, January 24–27, will reach a new high in I.R.E history.

Many problems must be met and solved by the various subcommittees because of wartime conditions but none is more critical than that of hotel reservations for out-of-town guests. With the opening date only a few weeks away, it is essential that members who will be present reserve their rooms at once. The hotel situation in New York has been complicated during the last month by a set-aside order to care for military personnel and their families but I.R.E. visitors can be accommodated if reservations are made at once.

The papers committee has announced that papers already in hand insure an interesting program. It is believed that a fairly complete agenda of the sessions will be available for the January issue of the PROCEEDINGS.

The Papers Committee has made a determined attempt to obtain papers that will be expressive of postwar problems and developments as well as of wartime technical activities. In hopes that the favorable progress of the war will relax present restrictions on certain electronic devices now playing a vital role in military maneuvers, the committee will hold open a certain amount of time for last-minute manuscripts.

It has already been planned to devote special sessions to the radio aspects of the industrial-electronics field, to recent advances in vacuum-tube theory and development, and to radio links and relays. The latter subject is a particularly live one now, with television and frequency modulation occupying the thoughts of postwar planners on mass communications.

From all indications the exhibits will be one of the most important features of the Winter Technical Meeting. The number of firms that already have requested display space is so much greater than the committee first estimated that additional room is being sought on the convention floor. Here, also, it is hoped that secrecy surrounding many war devices will be dropped sufficiently to permit the exhibition of some war equipment.

As explained in the November PROCEEDINGS the general committee has recognized the desire of convention guests for social meetings between sessions. The "cocktail party" on the evening of January 26 is only one of the social high spots. Special arrangements will be made to entertain the ladies who come to New York for the meeting. Details of these attractions should be completed in time for an announcement in the January issue.

National Electronics Conference

Attracted by a program of fifty outstanding technical papers on all branches of technical developments in electronics, 2191 engineers, scientists, and technical workers were officially registered and took part in the technical meeting, banquet, and luncheons of the first National Electronics Conference at the Medinah Club of Chicago on October 5, 6, and 7. While the majority of those attending the Conference were from the United States, representatives from government or commercial agencies of Argentina, Canada, China, England, France, Mexico, and Russia were also present. The most prominent Canadian representative was Ralph A. Hackbusch, vice-president of

The Institute of Radio Engineers. Other members of the I.R.E. Board of Directors who attended the conference were H. M. Turner, president; F. B. Llewellyn, A. B. Chamberlain, I. S. Coggeshall, H. J. Reich, E. F. Carter, and H. A. Wheeler.

After an address of welcome by O. W. Eshbach, dean of the Technological Institute, Northwestern University, the Conference was opened by Ralph R. Beal, assistant to the vice-president in charge of RCA Laboratories, who spoke on "Electronic Research Opens New Frontiers." In this address, the many possibilities for future developments in the field of electronics were ably outlined.

At the luncheon on Thursday, October 5, W. C. White, director of the electronics laboratory, General Electric Company, spoke on "Electronics in Industry." The many industrial applications of electron tubes, first extensively developed by communications engineers, were high-lighted in Mr. White's address. This luncheon was arranged by the Chicago Section of the American Institute of Electrical Engineers and R. C. Ericson, chairman of the Chicago Section, presided.

At the banquet on Thursday evening at which H. T. Heald, president of the Illinois Institute of Technology presided, there were 1185 guests. Electronic-wire recordings of five-minute talks by Rear Admiral Joseph R. Redman, Director of Naval Communications, and Major General H. C. Ingles, Chief Signal Officer, were heard. The topic of both talks was "What Electronics Has Meant to the Armed Forces."

The banquet address, "Triggers to Mass Actions" was given by Major Lenox Lohr, president of the Museum of Science and Industry. In this address, Major Lohr discussed certain factors which are responsible for concerted action of large groups of persons. This address was followed by a program of entertainment.

At the Friday luncheon, arranged by the Chicago Section of the I.R.E., at which W. O. Swinyard, chairman of the Chicago Section presided, all members of the Board of Directors who attended the Conference were honored guests. Professor Turner commented on the excellent program of technical papers, the evident interest in noncommunication topics, and the large attendance which exceeded that of any I.R.E. or A.I.E.E. technical meeting. Professor Turner also expresed the desire of the Institute to co-operate more fully with the Conference in its future meetings.

Friday evening an informal dinner-meeting was held to enable members of the Board of Directors to become better acquainted with I.R.E. members prominent in the activities of the Chicago Section. Those at this dinner included W. O. Swinyard, chairman of the Chicago Section, presiding; H. M. Turner, president of the Institute; Ralph A. Hackbusch, vice-president; F. B. Llewellyn, Kenneth Jarvis, A. B. Chamberlain, Alfred Crossley, A. B. Bronwell, H. C. Luttgens, L. E. Packard, D. E. Foster, V. J. Andrew, I. S. Coggeshall, A. W. Graf, secretary of the Chicago Section; Cullen Moore, vice-chairman of the Chicago Section; A. H. Brolly, Paul Smith, H. J. Reich, R. H. Herrick, E. F. Carter, H. A. Wheeler, and Beverly Dudley. B. E. Shackelford was present for a few moments, but a previous engagement prevented him from taking part in the discussion.

At the I.R.E. dinner-meeting, Mr. Wheeler reported that he had been commissioned by the Board of Directors to extend the whole-hearted co-operation of the national body of the Institute in furthering the activities of the National Electronics Conference. He expressed the hope that the Conference would call on the I.R.E. as a means of promoting common interests. It was pointed out by Mr. Swinyard that the Chicago Section of the I.R.E. had only a minority voice in the Executive Committee of the Conference, but that a sufficient number of Committee members was present to convey the Board's thoughts accurately. The meeting was then opened for discussion of methods of co-operation and general Institute matters. The principal topic of discussion was the need for expanding the field of interest of the I.R.E. in a definite and concrete way that would be immediately apparent to all members.

Perhaps the outstanding significance of the Conference, so far as the I.R.E. is concerned, is the unusually large attendance for a first meeting, indicative of the interest in all phases, of electronics, and the appreciable interest in noncommunication topics. The following tabulation gives some indication of the topics covered by the sixteen technical sessions of the Conference. It also indicates the comparative interest in various topics as judged by attendance at the technical sessions.

Technical Session	Approximate Attendance
1. Television	1000
2. Electronic Power Applications	200
3. Electronic Aids to Medical Science	100
4. Survey of Industrial Electronics	350
5. Radio	550
6. Electronic Measurements and Controls	950
7. Recent Developments in Theoretical Electronics	350
8. Electron-Tube Developments	700
9. Industrial Applications; Electronic Devices	600
10. Radio and Telephone Applications	300
11. Ultra-High Frequencies	600
12. High-Frequency Heating	700
13. Industrial Radiography	200
14. Aeronautical Applications	110
15. Recent Developments in Electron Theory	800
16. Industrial Applications	300

Several hundred persons also attended educational motion pictures illustrating the principles of electronic devices or dealing with the manufacture of equipment.

The numerous expressions of interest for continuing the Conference and the success of the first meeting makes it possible to announce the holding of the second National Electronics Conference in Chicago in October, 1945.

BEVERLY DUDLEY

Correspondence

Correspondence on both technical and nontechnical subjects from readers of the PROCEEDINGS OF THE I.R.E. is invited, subject to the following conditions: All rights are reserved by the Institute. Statements in letters are expressly understood to be the individual opinion of the writer, and endorsement or recognition by the I.R.E. is not implied by publication. All letters are to be submitted as typewritten, double-spaced, original copies. Any illustrations are to be submitted as inked drawings. Captions are to be supplied for all illustrations.

Sources of Mica

To the Editor: September 6, 1944

Dear Sir:

I have received a letter from Mr. H. W. Eckweiler, Industrial Specialist, Mica-Graphite Division, War Production Board, in which he calls attention to a misstatement regarding the mica for radio condensers from India, appearing in the second sentence of my paper "Equipment and method for measurement of power factor of mica," published in the July, 1944, issue of the PROCEEDINGS on pages 393–397. The objection is to the last clause in the following sentence as published, "A very large part of the mica used in this country for radio condensers has been obtained abroad in the past, from India in particular, but this supply has been practically eliminated." Mr. Eckweiler says that this clause is incorrect and thinks that a correction should be published.

Quoting from Mr. Eckweiler's letter of August 29:

"Prior to the war, our main sources of mica were India and Brazil, but due to increased use for war purposes, it became necessary to develop other sources and expand the existing sources of supply. Due to various factors, such as reluctance of the trade to use mica from untried sources, the demand for mica of Indian origin was greater than the supply. Hence, many felt that Indian imports were disappearing, although, in fact, they were increasing. It became necessary for consumers to use mica from other sources, domestic and foreign, where classification and grading was not up to the Indian standards in many instances. This has been corrected to a great degree, and today, mica from other sources is being used with complete satisfaction for most critical applications.

"We realize that much misinformation regarding mica has been circulated. This is probably due, in part, to the secrecy which has surrounded our mica programs. We, therefore, feel it desirable to correct the statement regarding the 'practical elimination of Indian imports.'

"I trust that you may be able to publish this in an early issue of the PROCEEDINGS in order to clear up any erroneous impression unintentionally created by the original statement."

Very truly yours,
E. L. Hall, Radio Engineer
National Bureau of Standards
Washington, D. C.

Contributors

Carlyle M. Ashley was born on August 17, 1899, and received the M.E. degree from Cornell University in 1924. He was associated with the Telluride Association and

Carlyle M. Ashley

with Carrier Engineering Corporation, Syracuse, New York, during 1916–1917, returning to that organization in 1924. He has remained there since that time, holding successive positions as test engineer, appliance engineer, project supervisor, and, at present, director of development.

Mr. Ashley has designed a wide range of air-conditioning equipment, including the Carrier Unit Air Conditioner, Carrier Safety Steam Ejector Railroad Air Conditioner, and a complete range of air-conditioning and refrigerating equipment. He is the holder of numerous patents. Mr. Ashley is a member of the American Society of Heating and Ventilating Engineers and of the American Society of Refrigeration Engineers.

❖

G. L. Beers (A'27–M'29–SM'43) was born at Indiana, Pennsylvania, in 1899. He received the B.S. degree in electrical engineering from Gettysburg College in 1921. Mr. Beers was in the graduate-student

G. L. Beers

course and engineering school of Westinghouse from 1921 to 1922; in the radio engineering department of the Westinghouse Electric and Manufacturing Company, in charge of superheterodyne receiver development, from 1922 to 1930; section engineer in the research department of the RCA Manufacturing Company from 1930 to 1940; in charge of the advanced development division from 1940 to 1942; manager of the engineering and manufacturing service division 1942 to 1943; and since 1943 on the engineering administration staff.

❖

E. M. Guyer (A'32) was born at Cincinnati, Ohio, in 1900. He received the A.B., M.S., and Ph.D. degrees from the Uuiversity

E. M. Guyer

of Wisconsin in 1923, 1925, and 1929, respectively. From 1925 to 1929 he was assistant in the physics department at the University of Wisconsin, and engaged in research in geophysics and electrical prospecting.

From 1929 to date, Mr. Guyer has been connected with the research and development division of Corning Glass Works, engaged in research on dielectrics and development work on methods and equipment for electrical glass working. He is the inventor of the Corning system of high-frequency electrical glass sealing.

Mr. Guyer is a member of Phi Kappa Phi, Gamma Alpha, Sigma Psi, the American Association for the Advancement of Science, and the American Physical Society.

❖

Leonard R. Malling (A'31) was born in Acton, England, on July 9, 1909. He received the E.E. degree from Northampton Technical Institute, in England. From 1927 to 1931 he was associated with the research laboratories of Electrical and Musical Industries, and thereafter devoted one year to work on the International Telephone and Telegraph links, followed by a year in instrument development with Marconi-Ecko Company.

From 1934 to 1938 Mr. Malling was engaged in television research with the Baird Television Company in England. In 1938 he engaged in work on television research

Leonard R. Malling

and electronic war developments for Hazeltine Electronic Corporation, New York, and from 1943 to 1944 was associated with the University of California division of war research. At the present time Mr. Malling is doing research in the physical research department of Boeing Aircraft Company, at Seattle, Washington.

❖

William H. Parker, Jr., (A'36) was born at Everett, Massachusetts, on August 7, 1906. He received his education at the Massachusetts Institute of Technology from 1925 to 1929, returning to that institution for graduate work in 1931 and 1932.

During 1929 and 1930 Mr. Parker was a member of the engineering staff of the Amrad Corporation. In 1935 he became an assistant radio engineer for the United American Bosch Corporation, and from 1936 to 1938 was a police radio engineer. He was employed as an engineer for Fada Radio and Electric Company from 1938 to 1941,

William H. Parker, Jr.

and as a receiver design engineer for the Federal Telegraph Company in 1941 and 1942. Since that time he has been with the Stromberg-Carlson Company as project engineer.

❖

Horace O. Parrack was born in Preston County, West Virginia, on September 16, 1905. He received the A.B. degree in 1929 from the University of West Virginia. In 1932 he received the M.A. and in 1940 the Ph.D. in physiology from Columbia. He was

Horace O. Parrack

an instructor in zoology from 1929–1931 and instructor in physiology from 1934–1939 at Columbia. He was a Porter Fellow at Harvard during 1939–1940 and an Austin Teaching Fellow in Harvard Medical School in 1940. Dr. Parrack's research has been in electrophysiology. He is now a Captain in the Army of the United States.

❖

William M. Rogers was born in Jennings, Florida, on September 18, 1900. He received the B.S. degree from the University of Georgia in 1921 and, in 1927, the Ph.D. degree from Cornell University where he was an instructor from 1924 to 1927. During 1927 to 1928 he was an instructor in anatomy at University and Bellevue Medical College and from 1928 to 1931 an instructor at the College of Physicians and Surgeons, Colum-

William M. Rogers

bia University. Dr. Rogers is now assistant professor of anatomy at Columbia where he is carrying on experimental research in neuroembryology and neurophysiology. One phase of this work has been the application of electronic apparatus to the study of peripheral nerve injuries.

❖

J. G. Rountree (A'39–M'44) was born in Bee County, Texas, on January 7, 1914. He received the B.A. degree with honors

J. G. Rountree

from the University of Texas in 1937, having majored in physics. During his senior year, he was employed by KNOW, Austin, Texas, and on graduation, he entered the employ of KTSA, San Antonio. In 1939, he was employed by WBAP, Fort Worth, and in September, 1941, he joined the field division of the engineering department of the Federal Communications Commission as radio inspector. From May, 1942, to November, 1943, he was attached to Headquarters New Orleans Air Defense Region as a civilian liaison officer.

❖

Samuel Sabaroff

❖

Mr. Rountree has been active in amateur radio circles since 1932, holding a license for amateur station W5CLP.

❖

Samuel Sabaroff (A'42) was born in Philadelphia, Pennsylvania, on November 10, 1908. In 1931 he received the B.S. degree in electrical engineering from Drexel Institute and in 1937 of the M.S. degree from the University of Pennsylvania. From 1931 to 1932 he was in the reject-control and factory laboratory of the Philco Radio and Television Corporation. Since 1932 Mr. Sabaroff has been a transmitter engineer with the WCAU Broadcasting Company. He is also employed as consultant in defense work.

Proceedings *of the* I·R·E

Published Monthly by

The Institute of Radio Engineers, Inc.

VOLUME 32—1944

The Institute of Radio Engineers, Inc.
330 West 42nd Street
New York 18, N.Y.

GENERAL INFORMATION

The Institute

The Institute of Radio Engineers serves those interested in radio and allied electrical-communication fields through the presentation and publication of technical material.

Membership has grown from a few dozen in 1912 to more than twelve thousand. There are several grades of membership, depending on the qualifications of the applicant, with dues ranging from $3.00 per year for Students to $10.00 per year for Senior Members and Fellows.

PROCEEDINGS, Standards Reports, and any other material published in a given year are sent to members without further payment for that year.

The PROCEEDINGS

The PROCEEDINGS has been published without interruption from 1913 when the first issue appeared, Over 2400 technical contributions have been included in its pages and portray a currently written history of developments in both theory and practice. The contents of every paper published in the PROCEEDINGS are the responsibility of the author and are not binding on the Institute or its members. Text material appearing in the PROCEEDINGS may be reprinted or abstracted in other publications on the express condition that specific reference shall be made to its original appearance in the PROCEEDINGS. Illustrations of any variety may not be reproduced, however, without specific permission from the Institute.

The first issue of the PROCEEDINGS was published in 1913. Volumes 1, 2, and 3 comprise four issues each. Volume 4 through volume 14 contain six numbers each and each succeeding volume is made up of twelve issues.

In 1939, the name of the PROCEEDINGS of the Institute of Radio Engineers was changed to the PROCEEDINGS OF THE I.R.E. and the size of the magazine was enlarged from six by nine inches to eight and one-half by eleven inches.

Subscriptions

Annual subscription rates for the United States of America, its possessions, and Canada, $10.00; to college and public libraries when ordering direct, $5.00. Other countries, $1.00 additional.

Back Copies

The Institute endeavors to keep on hand a supply of back copies of the PROCEEDINGS for sale for the convenience of those who do not have complete files. However, some issues are out of print and cannot be provided.

All back issues of the PROCEEDINGS OF THE I.R.E., which are available, are priced at $1.00 per copy. Price includes postage in the United States and Canada. Postage to other countries is ten cents per copy.

A discount of 25 per cent will be allowed to members of the Institute in good standing; accredited public and college libraries will be granted a discount of 50 per cent.

1913–1915 Volumes 1–3 Quarterly
1913 Vol. 1 January (a reprint)
1916–1926 Volumes 4–14 Bimonthly

1917	Vol. 5.	April, June, August, October
1918	Vol. 6	April, August, December
1919	Vol. 7	December
1920	Vol. 8	April, June, August, October, December
1921	Vol. 9	All 6 issues
1922	Vol. 10	All 6 issues
1923	Vol. 11	All 6 issues
1924	Vol. 12	October, December
1925	Vol. 13	April, June, August, October, December
1926	Vol. 14	All 6 issues

1927–1938 Volumes 15–26 Monthly

1927	Vol. 15	April, May, June, July, October, December
1928	Vol. 16	February to December, inc.
1929	Vol. 17	April, May, June, November
1930	Vol. 18	January, April to December, inc.
1931	Vol. 19	February, March, May, June, July, September to December, inc.
1932	Vol. 20	January, March to December, inc.
1933	Vol. 21	All 12 issues
1934	Vol. 22	All 12 issues
1935	Vol. 23	All 12 issues
1936	Vol. 24	January to April, inc., June
1937	Vol. 25	February to December, inc.
1938	Vol. 26	All 12 issues

1939–1942 Volumes 27–30 Monthly
New Format—Large Size

1939	Vol. 27	January to March, inc., May, June, December
1940	Vol. 28	All 12 issues
1941	Vol. 29	All 12 issues
1942	Vol. 30	January, February, April, October to December, inc.
1943	Vol. 31	March to December, inc.
1944	Vol. 32	January, February, June to December, inc.

Contents of Volume 32—1944

Volume 32, Number 1, January, 1944

Volume 32, Number 2, February, 1944

Volume 32, Number 3, March, 1944

Volume 32, Number 4, April, 1944

Volume 32, Number 8, August, 1944 (Cont.)

Volume 32, Number 9, September, 1944

Volume 32, Number 9, September, 1944 (Cont.)

Volume 32, Number 10, October, 1944

Volume 32, Number 11, November, 1944

Volume 32, Number 11, November, 1944 (Cont.)

Volume 32, Number 12, December, 1944

INDEX TO AUTHORS

Numbers refer to the chronological list. Light-face type indicates papers, **bold-face** type indicates discussions, and *italics* refer to books and book reviews.

INDEX TO SUBJECTS

This listing includes technical, sociological, economic, and general papers as well as books and book reviews.

D

E

NONTECHNICAL INDEX

Election of Officers

Miscellaneous

Photographs

Report of the Secretary—1943

Representatives in Colleges

Representatives on Other Bodies

Resolution

Standards

trace THIS FIGHTER'S RECORD BY HIS MEDALS!

"Captain Dag"

If there were decorations for industrial heroes, Mr. Dag would be a much be-ribboned gentleman. Perhaps we should call him 'Captain' Dag, because he commands so versatile a company of physical and chemical properties.

Captain Dag (a campaigner who will never be mustered out) represents Dag brand colloidal graphite, the smooth, black liquid concentrate which serves so many different war industries. Capt. Dag may take the form of a dry film, a fluid film, a surface coating, an impregnation, etc.

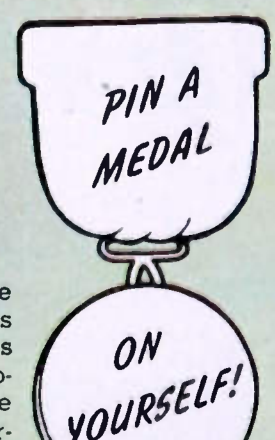
PHYSICAL AND CHEMICAL PROPERTIES

1. Slippery—A Good Lubricant. Softer than Talc
2. Conducts Electricity
3. Withstands Temperature Extremes
4. Absorbs, Radiates and Conducts Heat
5. Maximum Purity
6. Low Coefficient of Expansion
7. Particles Bear Like Electric Charges
8. Insoluble in Acids and Alkalies
9. Black and Opaque
10. Gas Adsorbent
11. Little Photoelectric Effect
12. Miscible with Most Fluids
13. Films Adhere Tenaciously and Dry with Sharp Edges
14. Microscopically Fine Particles. Penetrates Fine Pores
15. An Excellent Suspension

1, 3, 8, 14, 13, 6
CITATION: "We have been enthusiastic users of Dag colloidal graphite for more than ten years. We find it the only material which will prevent bolts, nuts and flanges from seizing under the high temperature and pressure conditions in our boilers and steam systems."

2, 4, 13, 10, 11, 3
CITATION: "Graphite films when applied to the grids (and frequently the plates) of radio tubes for receiving and transmitting, are useful for minimizing secondary emission, 'back' emission and photoelectric effects."

1, 3, 13, 14
CITATION: "Dry films formed from Dag colloidal graphite supply durable lubrication on parts which could not be effectively lubricated otherwise. Such films are functioning at temperatures from (—60° F. to +1200° F.) and higher."



For easy reference we've given colors to Captain Dag's most valuable properties. Match these colors with the performance "citations" above. Then pin a medal on yourself for putting Captain Dag to work in your plant. He's one campaigner who won't be mustered out.

dag COLLOIDAL PRODUCTS

ACHESON COLLOIDS CORPORATION

PORT HURON, MICHIGAN

ELECTRONIC RESEARCH FOR INDUSTRY

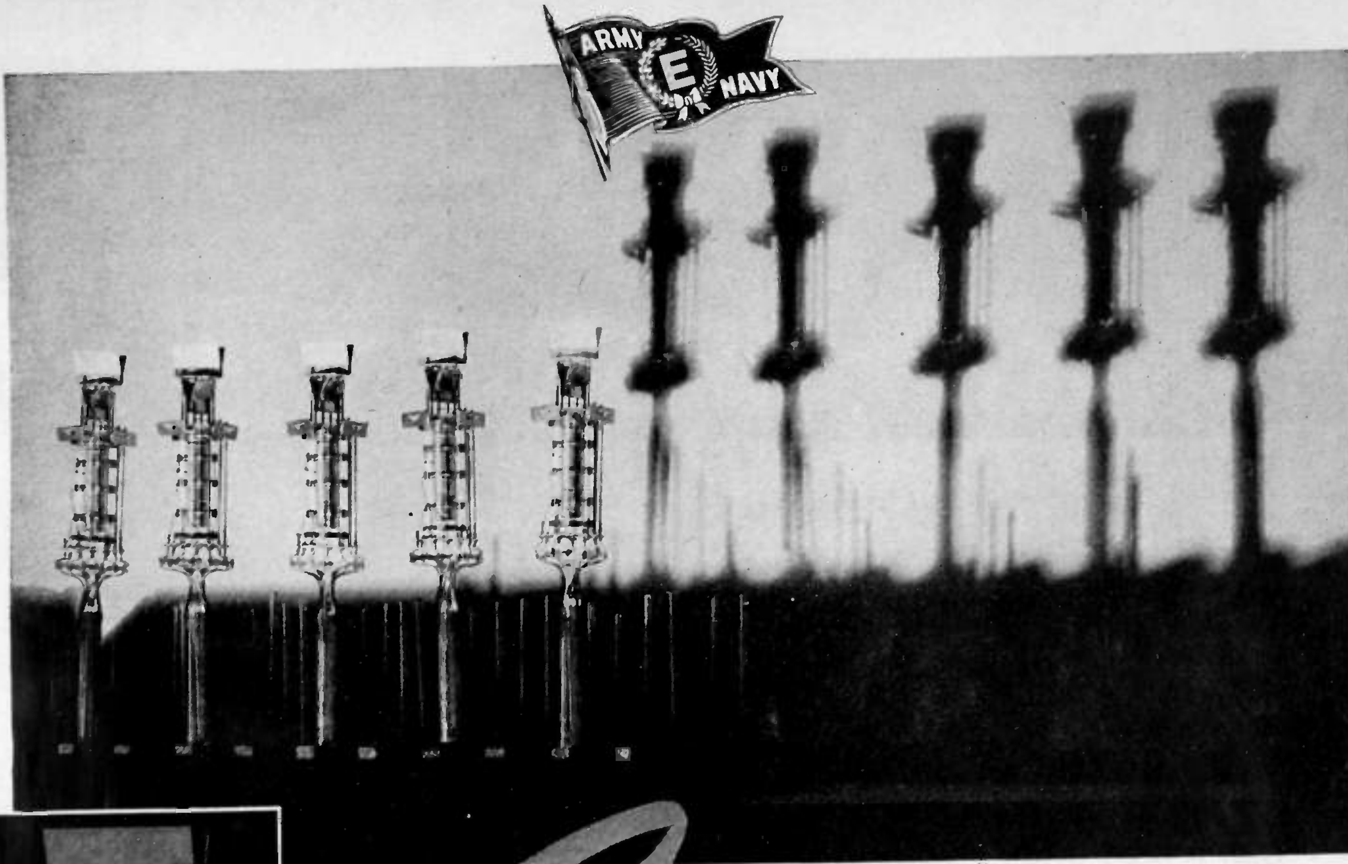
The National Union Laboratories are now available to complete your established engineering facilities

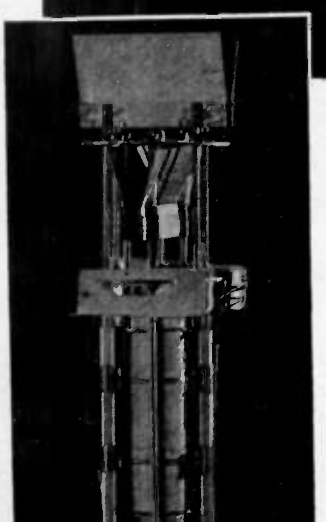
There is no need to postpone your electronic research program, awaiting the day when competent engineers, costly equipment and scarce materials can be obtained. You can start right now and be far ahead by having National Union Laboratories take over this highly specialized part of your work, thus rounding out the development activities of your existing engineering group.

Whether you are interested in a single project or a complete service—we invite you to investigate National Union Electronic Research. Let's talk it over. There is no obligation whatever. Please address inquiries to Department D.

NATIONAL UNION RESEARCH LABORATORIES

National Union Radio Corporation **Newark 2, New Jersey**





Guns FOR VICTORY!

Recently the Army-Navy "E" for production excellence was awarded to Allen B. DuMont Laboratories, Inc. In accepting this high honor, Allen B. DuMont said in part:

"Originally the Navy 'E' went to that ship scoring outstanding marksmanship. Today that 'E' again reverts to its original meaning. We of the DuMont organization make *electronic guns.* Each cathode-ray tube contains an electronic gun. We make those guns as accurately as our skill, ingenuity and conscientious inspection can make them. Thus I hope that our 'E' is the direct result of good electronic marksmanship, as reflected by the reports from various battlefronts."

Electronic guns for victory! Such is the DuMont contribution to the war effort, made possible *qualitatively* by years of pioneering experience, and now *quantitatively* as well by a 400% growth in personnel. In four large DuMont plants and in several DuMont laboratories, continuing electronic victories are assured for winning today's war and tomorrow's peace.

SUBMIT YOUR CATHODE-RAY PROBLEMS . . .

DUMONT *Precision Electronics & Television*

ALLEN B. DUMONT LABORATORIES, INC., PASSAIC, NEW JERSEY • CABLE ADDRESS: WESPEXLIN, NEW YORK

SECTION MEETINGS

BUFFALO-NIAGARA

"Meters for Electronic Measurements," by W. Bergerson, Electrical Instrument Laboratories; October 18, 1944.

CHICAGO

"Scientific Approach to Problems in Industrial Electronics," by J. C. Frommer, Bell and Howell Company; October 20, 1944.

"Unusual Tube Circuits," by E. C. Kent, C. G. Conn, Ltd.; October 20, 1944.

CINCINNATI

"Becoming a Registered Professional Engineer," by Alfred LeFeber, Ohio Society of Professional Engineers; September 19, 1944.

DALLAS-FORT WORTH

"Measurement Scales Used in Communication Engineering," by N. B. Fowler, American Telephone and Telegraph Company; October 6, 1944.

DAYTON

"Industrial Electronics," by E. F. W. Alexanderson, General Electric Company; October 26, 1944.

Movies, "Frequency Modulation," and "Television," General Electric Company; October 26, 1944.

EMPORIUM

"Multiform Process Glass," by George Bair, Corning Glass Works; October 17, 1944.

INDIANAPOLIS

"Development and Operation of the Signal Corps Radio Equipment Type SCR 284," by H. V. Noble, Crosley Radio Corporation; September 22, 1944.

MONTREAL

"What Frequency-Modulation Radio Can Do For Canada," by W. G. Broughton, General Electric Company; October 11, 1944.

NEW YORK

"Program-Transmission Circuits for Frequency-Modulation Broadcast Stations," by E. W. Baker, American Telephone and Telegraph Company; October 4, 1944.

OTTAWA

"What's New in Science and Engineering," by E. S. Lee, General Electric Company; September 21, 1944.

"Frequency Modulation," by W. G. Broughton, General Electric Company; October 10, 1944.

PHILADELPHIA

"Coupled Circuits," by H. M. Turner, President, Institute of Radio Engineers, October 3, 1944.

PORTLAND

"Voltage Regulators," by W. R. Hill, University of Washington, October 13, 1944.

ST. LOUIS

"Wave Guides and Coaxial Transmission Lines," by Harner Selvidge, Fournier Institute, September 21, 1944.

TWIN CITIES

"Frequency Modulation in Practice," by J. D. Klug, KSTP; October 10, 1944.

WASHINGTON

"A Frequency-Dividing Locked-In Oscillator Frequency-Modulation Receiver" by G. L. Beers, Radio Corporation of America; October 9, 1944.

WILLIAMSPORT

"Standardization of Radio Tubes," by Jerry Steen, Sylvania Electric Products, Inc.; October 6, 1944.

"Klystron Operation," by A. E. Harrison, Sperry Research Laboratories; October 20, 1944.

Centralab

CERAMIC CAPACITORS for HIGH VOLTAGE

Three new double cup style ceramic capacitors engineered by Centralab for transmitter applications where high working voltages and loads are required.

Type 850 currently available with two terminal styles — axial screw type and lug style . . . or one of each. Capacities ranging from 25MMF NPO to 100MMF N750. Working voltage to 10,000 D.C. Type 851 available with two terminal styles as illustrated. Capacities ranging from 25MMF NPO to 200 MMF N750. Working voltage to 20,000 D.C.

Type 852 designed to withstand shock of 100 to 200 G. Axial screw style terminal. Capacities range from 10MMF NPO to 25MMF N750. Working voltages to 10,000 D.C. Ask for Bulletin 721 and 814.

Producers of Variable Resistors • Selector Switches • Ceramic Capacitors, Fixed and Variable • Steatite Insulators.

Centralab

Division of GLOBE-UNION INC., Milwaukee

MEMBERSHIP

The following admissions and transfers (November) were approved on October 31, 1944.

Transfer to Senior Member

Ball, I. D., 419 Marshall St., Allegan, Mich.
Bennett, H. S., Hq. SCIA, 19 W. Fourth St., Dayton 2, Ohio
Biskner, L. J., Newark Athletic Club, 16 Park Pl., Newark, N. J.
Bond, M. E., 301 Addison St., Elmhurst, Ill.
Buckthal, E. P., 5959 S. Cicero Ave., Chicago, Ill.
Clapp, R. G., 215 W. Montgomery Ave., Haverford, Pa.
Dunlap, O. E., Jr., 19 Barstow Rd., Great Neck, L. I., N. Y.
Duttera, W. S., 35 Hampton Rd., Lynbrook, L. I., N. Y.
Eichel, J. H., Federal Communications Commission, 641 Washington St., New York 14, N. Y.
Glover, R. P., 1024 Superior St., Oak Park, Ill.
Graham, B., c/o Sparton of Canada, Ltd., London, Ont., Canada
Hallman, L. B., Jr., 3 Crescent Blvd., Dayton, Ohio
Harries, J. H. O., 11 Waterloo Pl., Pall Mall, London, S. W. 1, England
Hutcheson, G. C., Columbia Broadcasting System, 485 Madison Ave., New York 22, N. Y.
Levy, G. F., 8051 S. St. Lawrence Ave., Chicago 19, Ill.
Lyman, H. J., 400 W. Hudson Ave., Royal Oak, Mich.
Lytle, C. W., 4 Erie St., Oak Park, Ill.
Marble, F. G., 63 Greenhurst Rd., West Hartford 7, Conn.
Martin, V. G., 75 Mildorf St., Rochester 9, N. Y.
Mesa, J. O., 1826 Diversey Pkwy., Chicago 14, Ill.
Myer, D. A., Westinghouse Radio Stations, 1619 Walnut St., Philadelphia, Pa.
Ouimet, J. A., 1440 St. Catherine St. W., Montreal, Quebec, Canada
Passow, E. B., 822 S. Hamlin, Park Ridge, Ill.
Petry, C. A., Superintendent of Communications, United Air Lines, Chicago 38, Ill.
Rankin, J. A., 5921 W. Dickens Ave., Chicago, Ill.
Reber, G., 212 W. Seminary Ave., Wheaton, Ill.
Roberts, H. C., 108 Talbot Laboratory, Urbana, Ill.
Schnell, W. J., 2001 Highland Ave., Wilmette, Ill.
Sherwood, E. T., Globe Union, Inc., 900 E. Keefe Ave., Milwaukee 1, Wis.
Tregidga, A. C., 4545 Augusta Blvd., Chicago 51, Ill.
Waidelich, D. L., Department of Electrical Engineering, University of Missouri, Columbia, Mo.
Wallace, J. D., 111 Eighth St., S.E., Washington 3, D. C.
Whinnery, J. R., 2047 Coolidge Pl., Schenectady, N. Y.
Willson, A. R., 8055—14 Ave., N.E., Seattle 5, Wash.

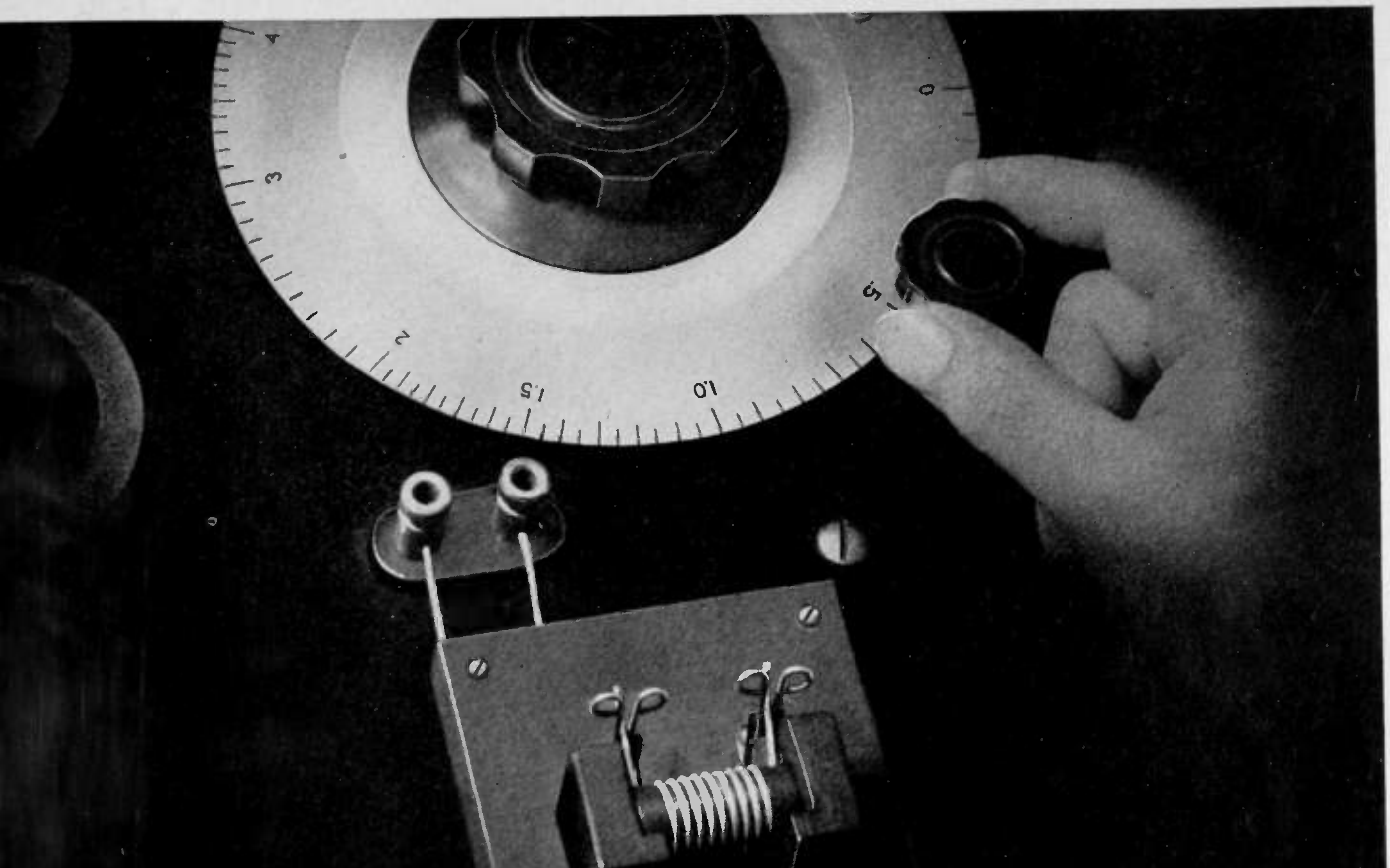
Admission to Senior Member

Bennett, R. D., Naval Ordnance Laboratory, Navy Yard, Washington, D. C.
Dickieson, A. C., Bell Telephone Laboratories, 180 Varick St., New York, N. Y.
Short, W. P., 230 Albany St., Cambridge, Mass.
Stedman, C. K., 2416 Rosemont Pl., Seattle, Wash.
Thompson, B. V., 179 Walnut St., Montclair, N. J.

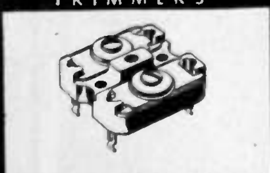
Transfer to Member

Alberts, W. S., 6430 McHugh Pl., Cincinnati 13, Ohio
Alexander, M. S., 2289 Memorial Drive, S.E., Atlanta, Ga.
Atwood, H., Jr., 254 Joralemon St., Belleville 9, N. J.
Barnes, P. C., WFAA-WBAP, Grapevine, Texas

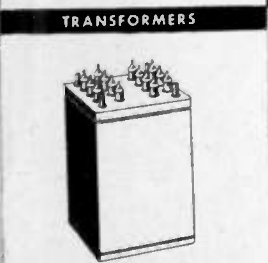
(Continued on page 38A)



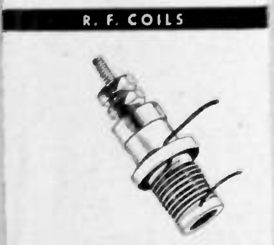
TRIMMERS



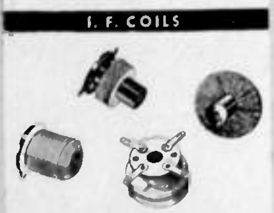
TRANSFORMERS



R. F. COILS



I. F. COILS



CHOKE COILS

CRUCIAL MOMENT

The indispensable attribute of a component destined for an assembly line is absolute uniformity.

The "Crucial Moment" in the manufacture of a coil is the measurement and adjustment point, at which this uniformity is achieved.

Our years of experience assure the best in production testing apparatus. Our Engineering is equipped for the most elaborate basic type testing . . . at high and low temperatures . . . extremes of humidity . . . under vibration and impacts and electrical characteristics at low or high frequencies.

For your requirements . . . whether coils or trimmers, depend on *AUTOMATIC* for uniformity and reliability at no greater cost.

KEEP BACKING THE ATTACK!
BUY MORE WAR BONDS

AUTOMATIC WINDING CO., INC.

COMPLETE ELECTRONIC ASSEMBLIES & COMPONENT PARTS

900 PASSAIC AVE. EAST NEWARK, N. J.

MEMBERSHIP

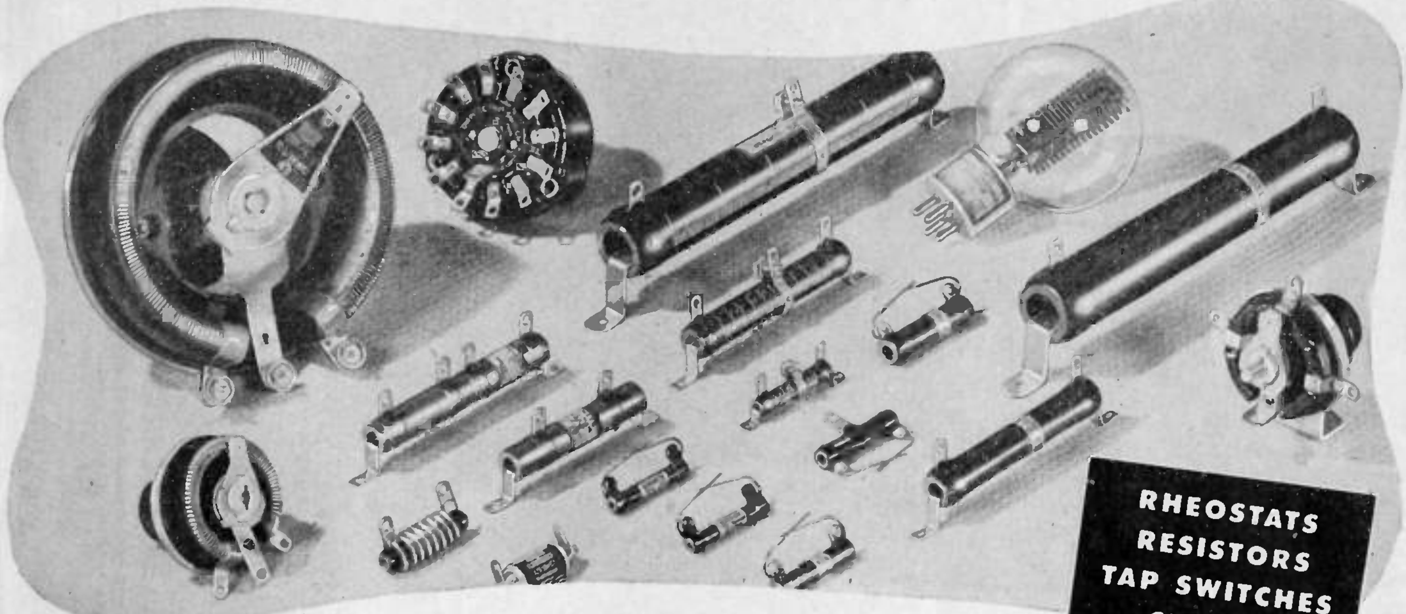
(Continued from page 36A)

Baylor, A. D., 4623 Mayhew Ave., Cincinnati, Ohio
Bereskin, A. B., 452 Riddle Rd., Cincinnati, Ohio
Broding, R. A., 2921 Kingston, Dallas 11, Texas
Brouse, H. L., Crosley Corporation, Cincinnati 25, Ohio
Butts, R. S., Box 1403, Cincinnati 1, Ohio
Byer, E. D., 8340—16 St., N.W., Seattle, Wash.
Campbell, J. S., 1543—19 St., N., Arlington, Va.
Carlson, R. F., 108 E. Sixth St., Emporium, Pa.
Chaffee, R. E., 4 Hartford St., Dorchester, Mass.
Charp, S., 6228 Pine St., Philadelphia 43, Pa.
Christensen, A., 791 Western Ave., Glyn Ellyn, Ill.
Currier, S. E., 479 Baldwin Rd., Maplewood, N.J.
Day, C. E., 6 Bachman St., Cincinnati 18, Ohio
Day, G., 697 Sterling Pl., Brooklyn 16, N. Y.
Dempster, B., c/o Crosley Corporation, Cincinnati, Ohio
Edwards, W. E., Radio Materiel Office, Navy Yard 128, c/o F.P.O., San Francisco, Calif.
Eldridge, H. C., Jr., 227 Oxford Rd., Franklin, Ohio
Erickson, P. W., Sylvania Electric Products Inc., Williamsport 1, Pa.
Freitag, W. O., Rt. 1, Box 713, La Canada, Calif.
Fromm, W. E., 150 Old Country Rd., Mineola, L. I., N. Y.
Frost, F. N., 7727—34 Ave., N.E., Seattle, Wash.
Furst, U. R., 4727 N. Malden St., Chicago 40, Ill.
Hall, W. M., 1357 Massachusetts Ave., Lexington 73, Mass.
Hauber, E. N., 1028 N. Edgewood St., Arlington, Va.
Helt, S., Radio Building, Short and Walnut Sts., Lexington, Ky.
Herbert, C., U. S. Coast Guard District Office, Alaska Bldg., Seattle 4, Wash.
Hertzler, E. A., Pratt Institute, Ryerson St., Brooklyn 5, N. Y.
Hesse, H. R., 46 Hilbert St., Hempstead, L. I., N. Y.
Hilker, R., KSTP, Hotel St. Paul, St. Paul, Minn.
Himoe, C. E., 234 Lafayette Ave. S., Bremerton, Wash.
Hollis, J. L., 7317 Harding Ave., Cincinnati, Ohio
Horrell, M. W., 3042 Hull Ave., Cincinnati 11, Ohio
Hughes, E. J., Prevost 14209, Detroit 27, Mich.
Jensen, M. C., 128 Stevens Ave., West Hempstead, L. I., N. Y.
Kahl, E., 103 E. Fifth St., Emporium, Pa.
King, F. W., Jr., R.R. 9, Box 263-B, Cincinnati, Ohio
Knoblaugh, A. F., c/o The Baldwin Co., Gilbert Ave. and Eden Park Entrance, Cincinnati, Ohio
Krueger, R. M., 3402 W. Dickens Ave., Chicago, Ill.
Lantzer, F. N., R.R. 1, Mason, Ohio
Lepple, H., 4432 Raceview Ave., Cincinnati, Ohio
McDonald, J. M., 3379 Morrison Ave., Cincinnati, Ohio
McNeely, J. S., 802 Telephone Building, Dallas 1, Texas
Meissner, E. R., 203 S.W. Ninth Ave., Portland, Ore.
Mieher, W. W., 192 Jackson Ave., Mineola, L.I., N.Y.
Moore, K. A., 5102 Findlay St., Seattle, Wash.
Morgan, J. M., 698 Main St., Cranbury, N. J.
Nason, D. B., 1504 Hollywood Ave., Cincinnati, Ohio
Newberry, D. A., 746 Chesterfield Rd., Columbus, Ohio
Oker, W. A., 3306 Renfro Ave., Cincinnati, Ohio
Partridge, P. N., 16 Sherwood Rd., Silver Spring, Md.
Peterman, R. S., 714 Crozier Ave., Clearfield, Pa.
Phillips, L. B., 1620 Melvin Cir., Mt. Healthy, Ohio
Pierce, C. G., 225 Lockwood Rd., Syracuse 3, N. Y.
Quitter, J. P., 3557 Vine St., Cincinnati 20, Ohio

(Continued on page 40A)

OHMITE *Control* UNITS

GIVE ACCURATE, TROUBLE-FREE SERVICE



RHEOSTATS
RESISTORS
TAP SWITCHES
CHOKES

Designed and Built to Withstand

SHOCK
VIBRATION
TEMPERATURE EXTREMES
HUMIDITY
ALTITUDE

● Because they are so consistently reliable in actual service . . . Ohmite Rheostats, Resistors, Chokes and Tap Switches have become *"the control engineer's control units."*

Shown here are a few of the many types extensively used in military and industrial equipment. The wide variety of types and sizes in stock or special units provides a ready and exact answer to most applications.

In designing for war or postwar, let Ohmite experience help you.

OHMITE MANUFACTURING COMPANY
4862 Flournoy Street Chicago 44, U.S.A.

For helpful data and information, write on company letterhead for Industrial Catalog and Engineering Manual No. 40. Address Ohmite Manufacturing Co., 4862 Flournoy Street Chicago 44, Ill.

Be Right with **OHMITE**
RHEOSTATS • RESISTORS • TAP SWITCHES

MEMBERSHIP

(Continued from page 38A)

Schenck, R. L., 3313 Hildreth Ave., Cincinnati, Ohio
Schlegelmilch, R. O., 45 Lorindale Ave., Toronto, Ont., Canada
Schuck, O. H., 20 Hammond Rd., Belmont, Mass.
Sloan, C. B., 5565 Raceview Ave., Cincinnati, Ohio
Storck, H. C., 3723 E. Third St., Dayton 3, Ohio
Sumerlin, W. T., 5469 Village Green, Los Angeles 16, Calif.
Warriner, B., IV, 4012 Frankford Ave., Baltimore 6, Md.
Wedig, F. L., 1769 Dale Rd., Cincinnati 29, Ohio
Wissel, F. A., 3444 Oakview Pl., Cincinnati, Ohio
Wright, R. R., Box 65, Blacksburg, Va.
Young, P. A., 6202 Cortelyou St., Cincinnati, Ohio

Admission to Member

Ackard, W. C., 1st Radio Squadron, Patterson Field, Dayton, Ohio
Ayres, J. J., RD 1, Haddonfield, N. J.
Baker, Halsted W., Jr., 158 Watchung Ave., Chatham, N. J.
Becker, R. A., Applied Physics Laboratory, University of Washington, Seattle, Wash.
Bissonette, A. J., 28 Merzen Ct., Cincinnati, Ohio
Boeckerman, L. F., 728 Hodapp Ave., Dayton, Ohio
Boghosian, W. H., 463 West St., New York, N. Y.
Cherpeski, R. P., 1215 Weng Ave., Dayton, Ohio
Clarke, F. C., 1608 Arlington Ridge Rd. S., Arlington, Va.
Collins, F. E., 58 Sydney St., St. John, New Brunswick
Crapuchettes, P. W., 1507 Albany St., Schenectady, N. Y.
Curley, D. C., 502 New St., Clearfield, Pa.
Dietrich, D. J., 1809 E. Mound St., Springfield, Ohio
Evans, G. E., 148 Parmenter Rd., W. Newton, Mass.
Featherstone, S. J., 935 N. Limestone St., Springfield, Ohio
Freedman, S., Engineering and Repair Department, Submarine Base, New London, Conn.
Frihart, H. Neil, 2246 N. Springfield Ave., Chicago 47, Ill.
Goebel, E. S., 934 Pleasant, Oak Park, Ill.
Holmes, L. C., 37 West St., Fairport, N. Y.
Katz, L., 40 Brighton St., Dayton, Ohio
Lenkerd, J. P., 1154 Hancock Dr., N.E., Atlanta, Ga.
LeVelle, A. S., Rm. 810, Telephone Bldg., 308 S. Akard St., Dallas, Texas
Litchford, G. B., Apt. 9B, 35 Elk St., Hempstead, L. I., N. Y.
Loper, G. B., 421 E. Kolstad, Palestine, Texas
Lovett, W. S., 1855 Lincoln Dr., Williamsport, Pa.
Marchant, I. G., 7919 S. 112, Seattle, Wash.
Marmont, G. H., 4855 Fourth Ave., Detroit, Mich.
Marshall, R. W., 25 Wilmer St., Madison, N. J.
Mayfield, R. G., 1201 W. Lancaster, Fort Worth, Texas
Meltvedt, H., Pentagon Bldg., Rm. 2D316, Signal Corps Facilities Branch, Washington, D. C.
Miles, K. G., 8023 Eastern Ave., Silver Spring, Md.
Most, N., 612 Westbourne St., La Jolla, Calif.
Ostrander, G. D., 240 Randall Cir., Williamsport, Pa.
Pelton, R. G., Wilson C-12, Presidential Gdns., Alexandria, Va.
Peterson, E. F., 1971 Nott St., Schenectady, N. Y.
Popp, F. G., 270 Culver Rd., Rochester 7, N. Y.
Ringer, R. L., Jr., 2745 Hudson Blvd., Jersey City, N. J.
Saxon, M., P.O. Box 5238, Dallas 2, Texas
Schenck, A. K., Bell Telephone Laboratories, 180 Varick St., New York 14, N. Y.
Schock, J. O., 365 Stewart Ave., Garden City, L. I., N. Y.

(Continued on page 42A)

Rauland VISITRON Phototubes

FOR EVERY ELECTRONIC APPLICATION!

To say "Visitron Phototubes," is to say "finest in the field of light-sensitive devices." Their uniformity, dependability and high sensitivity through the years have brought recognized leadership to these quality products. • Most Visitron Phototubes are available in the vacuum type where a high degree of constancy and exact proportionality between light and current are required.

To be sure . . . specify VISITRON!

79A

59TA

51A

79A . . . designed for use in standard theatre projection equipment.

51A . . . universally used in portable 16 m. m. sound-on-film projection equipment.

59A . . . a popular model used in many makes of projectors. The 59TA is a special application of this tube, having a high dark resistance.

RADIO • RADAR • SOUND • **Rauland** COMMUNICATIONS • TELEVISION

Electroneering is our business

THE RAULAND CORPORATION • CHICAGO 41, ILLINOIS

Buy War Bonds and Stamps! Rauland employees are still investing 10% of their salaries in War Bonds

MEMBERSHIP

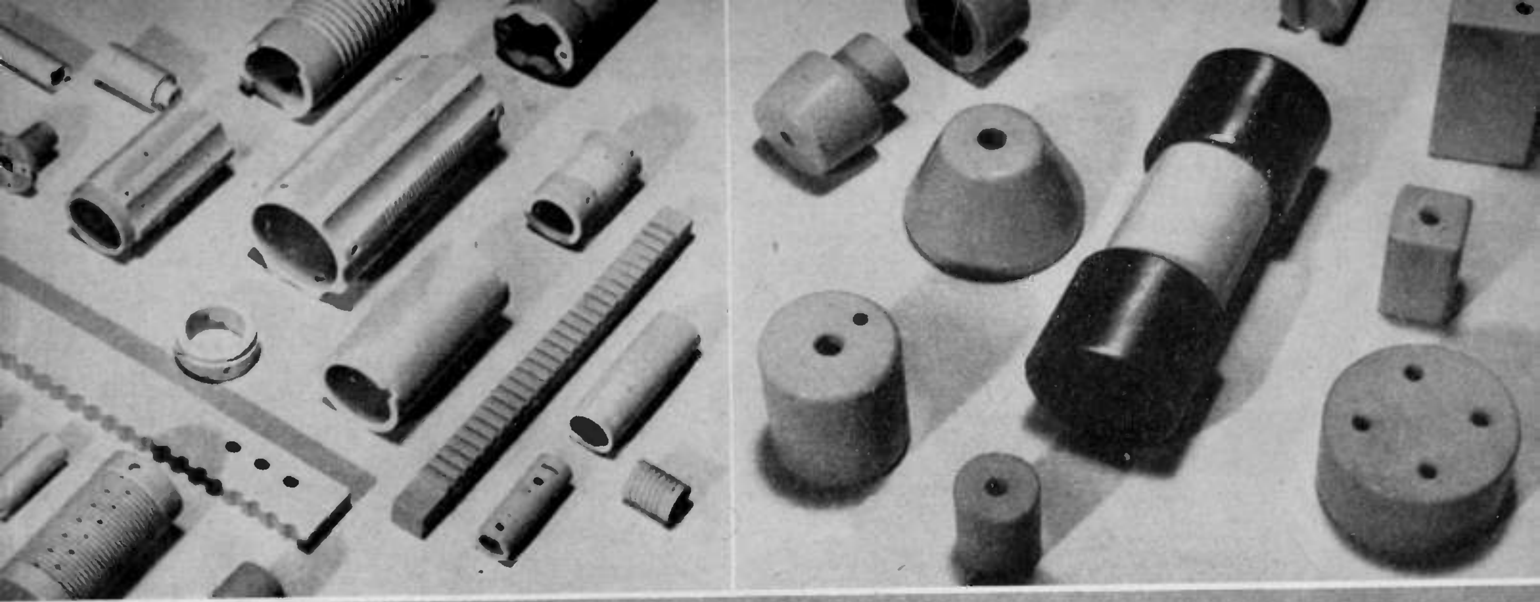
(*Continued from page 40A*)

Shaw, M. R., Jr., 215 Watauga Ave., Corning, N. Y.
Shearer, R. L., 1815—17th St., N.W., Washington, D. C.
Shirk, W. B., 5759 Kenneth Ave., Cincinnati, Ohio
Simmons, J. C., 22 Taft St., Lakeview, Hampstead, L. I., N. Y.
Smith, Archibald D., Jr., 72 Bennett Pl., Amityville, L. I., N. Y.
Smith, G. O., 2934 Feltz Ave., Cincinnati, Ohio
Smith, O. J. M., Electrical Engineering Department, University of Denver, Denver, Colo.
Stone, B. C., Westland Flatts, Smith's Parrish, Bermuda
Sunstein, D. E., 10 Spring Ave., Elkins Park 17, Pa.
Talley, T. J., III, 195 Broadway, Rm. 1735, New York, N. Y.
Van Winkle, E. W., 439 Edgewood Pl., Rutherford, N. J.
Voelker, W. D., Leeds and Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

Admission to Associate

Abramson, P., 2714 Wallace Ave., New York 67, N. Y.
Agnew, W. R., 153 Edgewood Ct., Dayton 7, Ohio
Beach, E. R., 1010 Lincoln Ave., Troy, Ohio
Beasley, R. R., 1306 W. Monroe St,, Phoenix, Ariz.
Beckhardt, T. G., 2228 E. 29 St., Brooklyn 29, N. Y.
Berk, R. B., 229 Yonge St., Rm. 417, Toronto, Ont., Canada
Best, C. A., Jr., 608 N. Pleasant, Jackson, Mich.
Blackett, L. G., 230 Keele St., Toronto, Ont., Canada
Blakely, K. H., 604 E. 12 St., Apt. 8, Indianapolis 2, Ind.
Blue, C. L., 3006 E. 78 St., Chicago 49, Ill.
Boote, E., Northern Electric Company, Box 369 Montreal, Que., Canada
Brainerd, H. B., 255 Marlborough St., Boston 16, Mass.
Bramley, N. V., 16 Lyndon Ave., Los Gatos, Calif.
Brazelton, M. W., 138 N. Hanover Ave., Lexington, 11, Ky.
Brent, L. L., 1330 N. Newstead Ave., St. Louis 13, Mo.
Britnell, P. R., 148 S. Munn Ave., East Orange, N. J.
Buie, J. G., Rt. 1, Box 7, Mertens, Texas
Bullis, E. E., Valparaiso Technical Institute, Valparaiso, Ind.
Bullock, J. M., Co. 1518 O.G.U., U.S.N.T.C., Great Lakes, Ill.
Butts, J. H., 215 W. 23 St., New York 11, N. Y.
Calderon, M. M., 333 Fifth St., West Des Moines, Iowa
Caranchini, S. A., 4325 Whitsett Ave., North Hollywood, Calif.
Carr, G. W., 1238 Susquehanna Ave., Sunbury, Pa.
Cary, C. A., Box 5, Cincinnati 24, Ohio
Chasan, L., Belvoir Rd., RD 4, Norristown, Pa.
Church, G. H., 5032 Nicollet Ave., Minneapolis, Minn.
Clardy, L., Research Laboratories, Swift and Company, U.S. Yards, Chicago 9, Ill.
Clayton, C. J., The Langham Hotel, Meyrick Rd., Bournemouth, England
Colodny, S. H., 390 E. Cliveden St., Philadelphia 19, Pa.
Cordeiro, A. A., Casa de Portugal, 630 Fifth Ave., New York, N. Y.
Crawford, W. C., 15 Wallace St., Whangarei, N. Z.
Crosfield, J. F., Witheridge, Beaconsfield, Bucks, England
Cupps, H. T., 1209 Edwards Ave., Lakewood 7, Ohio
Daugherty, R. H., Jr., American Telephone and Telegraph Company, 195 Broadway, New York 7, N. Y.
Davenport, F. S., BOQ 50A NATTC, Ward Island, Corpus Christi, Texas

(*Continued on page 44A*)



GREATER EFFICIENCY FOR YOUR 1945 DESIGNS.

MASTER of power and heat, ALSIMAG is the ideal insulation for tomorrow's Electronic devices.

ACCURATE—manufactured to close tolerances.

ECONOMICAL—because of high speed production methods.

ALSIMAG Steatite Ceramic Insulators are permanent materials. They are strong, hard and rigid—do not distort by loading, nor do they shrink with time. Impervious to heat up to 1000° C. Non-corrodible. Do not absorb moisture.

No matter what insulation you have been using, investigate ALSIMAG. Send us a sample or design drawing. Let us prove that ALSIMAG will meet your requirements for improved efficiency and performance.

Write for Property Chart containing complete data on physical characteristics.

AMERICAN LAVA CORPORATION
CHATTANOOGA 5, TENNESSEE

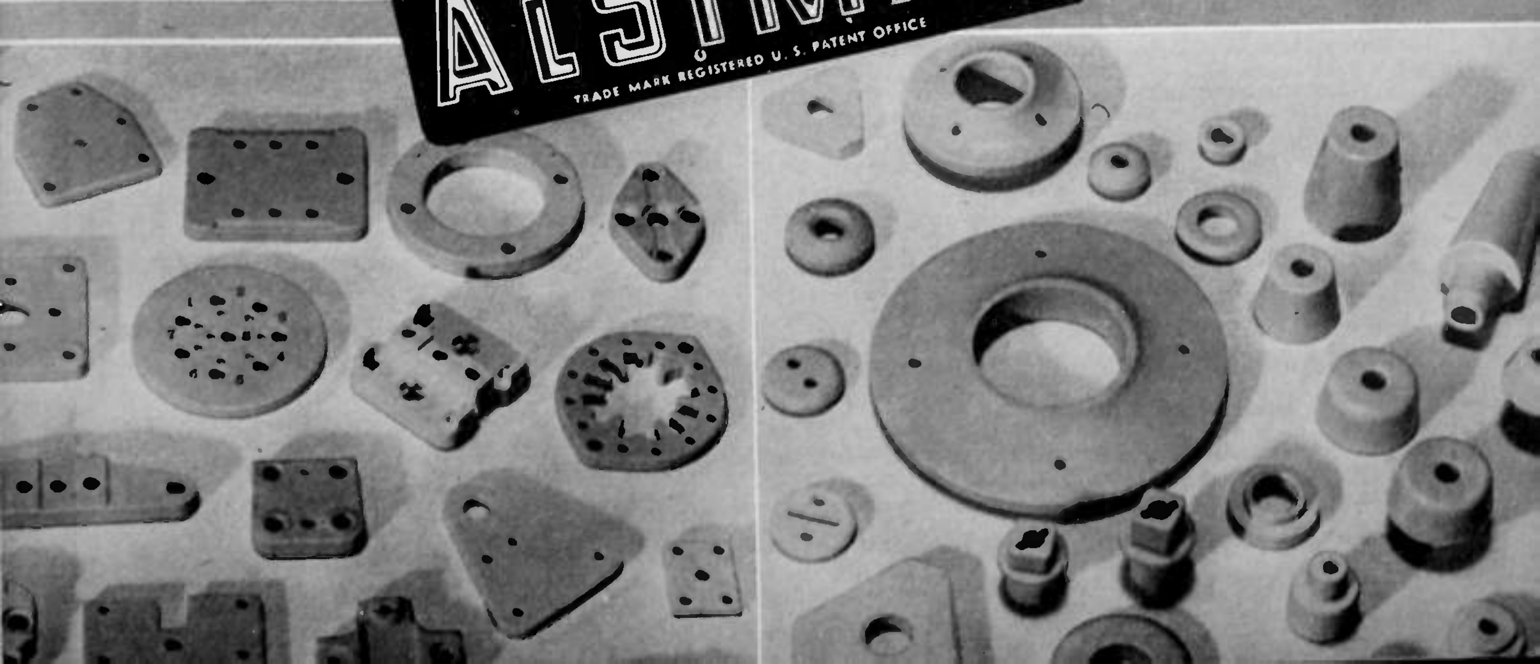
ND YEAR OF CERAMIC LEADERSHIP

CHARACTERISTICS OF ALSIMAG INSULATORS

- High Mechanicol Strength
- Permonent Rigidity
- Low-Loss Factor
- High Dielectric Strength
- Will Not Absorb Moisture
- Chemically Inert
- Heat Resistont
- Precision Mode of Purest Row Moteriols

ALCO has been awarded for the fourth time the Army-Navy "E" Award for "continued excellence in quantity and quality of essential war production."

ALSIMAG
TRADE MARK REGISTERED U. S. PATENT OFFICE



MEMBERSHIP

(Continued from page 42A)

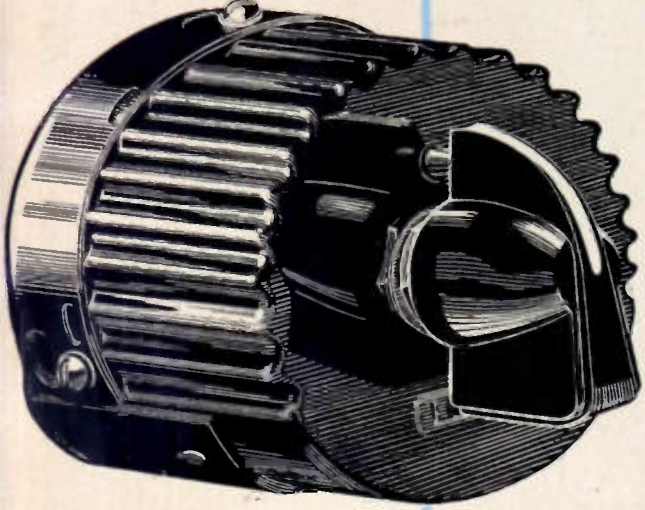
Dean, J. P., 1523 N. McCadden Pl., Hollywood 28, Calif.
Doidge, E. E., 5 Pepler Ave., Toronto, Ont., Canada
Eastlack, E. D., 1304 Virginia Ave., Manoa, Delaware County, Pa.
Edwards, C. V., 1025 Tabor St., Oklahoma City Okla.
English, W. C., 2878 N. Clark St., Chicago 14, Ill.
Feeney, C. J., 105 Surrey Lane, Hempstead, L. I., N. Y.
Fine, C. B., 805 E. Hamilton Ave., Ft. Wayne 5, Ind.
Fisher, L. C., 4476 Osprey St., San Diego 7, Calif.
Flansberg, S., 2903 W. Belmont Ave., Chicago 18, Ill.
Frampton, M. W., 1500 Fourth St., Santa Monica, Calif.
Fraser, J. S., Apt. 8, 550 McLaren St., Ottawa, Ont., Canada
Freed, A., 200 Hudson St., New York, N. Y.
French, H. A., 1043 Bergen St., Brooklyn, N. Y.
Garoff, K., 607 Bond St., Asbury Park, N. J.
Glovitsky, S. V., 832 W. 102 St., Los Angeles, 44, Calif.
Gould, H. J., 200 Caledonia Rd., Toronto, Ont., Canada
Granberry, H. W., 1050 University Pl., Schenectady 8, N. Y.
Grant, J. A., 3581 Benny Ave., Montreal, Que., Canada
Hachemeister, C. A., 2722 Newkirk Ave., Brooklyn 26, N. Y.
Hammond, A. L., 211 Third Ave., Asbury Park, N. J.
Harris, T. E., Jr., 1709 S. Court St., Montgomery 6, Ala.
Handley, E. E., 6184 Notre Dame de Grace Ave., Montreal, Que., Canada
Hawkins, J. E., 1612 South Evanston, Tulsa, Okla.
Haylock, F., 150-22 Third Ave., Whitestone, L. I., N. Y.
Hemphill, W. B., 4419 Southwestern Blvd., Dallas 5, Texas
Henderson, A. L., University of California, U.S.N. Radio and Sound Laboratory, San Diego, 52, Calif.
Heydenrych, J. C. R., c/o South Africa House, London, England
Hill, E. B., 541 W. 180 St., New York 33, N. Y.
Honea, L. W., 6205 Sligo Pkwy., Hyattsville, Md.
Jack, M. C., 324 Ponsenby Rd., Auckland, N. Z.
Jeffcott, F. B., 164 Rectory St., London, Ont., Canada
Kenny, H. J., R.C.A.F. Station, Rockliffe, Ont., Canada
King, F. H., Hotel Broadmoor, 3601 Connecticut Ave., N.W., Washington, D. C.
Koch, H. W., 23 Brooklyn Ave., West Hempstead, L. I., N. Y.
Koenig, G., RT 2, Box 551-A, Des Plaines, Ill.
La Via, J., 1473 Greene Ave., Ridgewood 27, N. Y.
Lawrance, R. T., 26 Waverly Ave., Dayton 5, Ohio
Lederer, E. H., 2021 Neil St., Schenectady 6, N. Y.
Lee, W. M., 1207 W. 47 St., Richmond 24, Va.
Lewis, G. W., 16 Lyndon Ave., Los Gatos, Calif.
Liebig, W. D., 211 E. Court St., Doylestown, Pa.
Lindemann, H. B., 14 S. Beechwood Ave., Catonsville, Baltimore 28, Md.
Linton, T. B., 5732 Duarte St., Los Angeles, 11, Calif.
Lomas, J. P., Radio Section, Wellington East Post, Office, Wellington, N. Z.
Macdonald, G. E., 1950 St. Luke, Montreal, Que., Canada
Manship, J. F., Box 394, c/o Mabel Manship, Wagoner, Okla.
Morris C. A., Sun Valley Rifle Range, Davisville, R. I.
Mohaupt, A. G., 6641 N. Fairfield Ave., Chicago 45, Ill.

(Continued on page 46A)

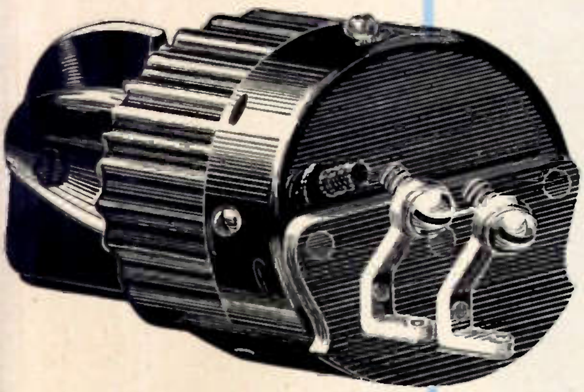
MEET IRC'S...

AN3155

POWER RHEOSTAT



AN3155
50-watt



AN3155
25-watt;
showing terminal
positions

Here's a power rheostat with a *short* past but a *long* future. Rugged in construction, light in weight and neat in appearance, it conforms in every respect to Army-Navy AN3155 specifications. It embraces all the features of IRC's well-known PR25 and PR50 rheostats.

Both the winding core and housing, of this completely sealed unit, are of aluminum to effect greater heat dissipation. To still further aid this important characteristic the housing is coated with a special heat-radiating finish developed by the IRC Research Staff. As a result the AN3155 generates a maximum temperature rise of only 170° as against an allowable 300°. Another feature of interest is the fact that the AN3155 can be operated at full power load in as low as 25% rotation.

Available in 25 or 50 watt models with either linear or tapered windings, the IRC AN3155 should find many useful post-war applications.

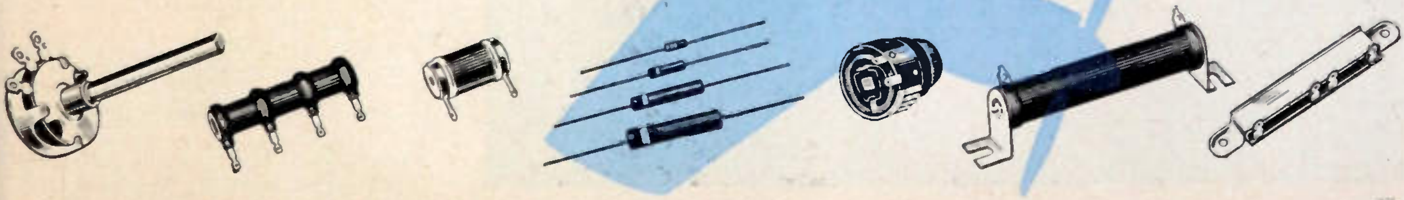
Technical data and further information will be sent on request.

PREFERRED FOR PERFORMANCE · IRC · FIXED & VARIABLE RESISTORS

INTERNATIONAL RESISTANCE CO.

401 N. Broad St., Philadelphia 8, Pa.

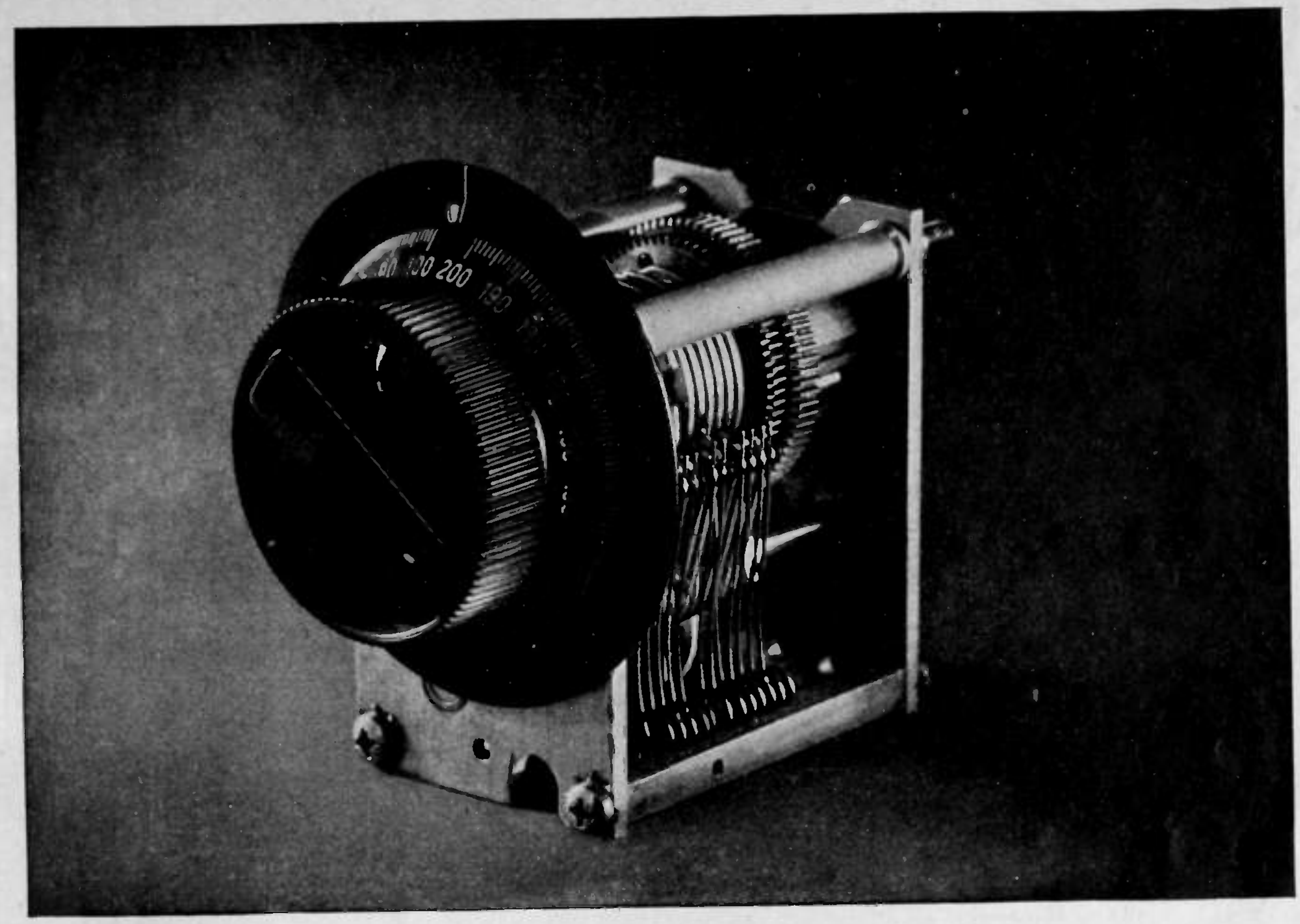
IRC makes more types of resistance units, in more shapes, for more applications than any other manufacturer in the world.



Membership

(Continued from page 44A)

Moates, O. E., 1301 Lamar, Wichita Falls, Texas
Mitchell, D. H., 1030 S. Highland St., Arlington, Va.
Melton, G. H., 1226 Wisconsin Ave., N.W., Washington 7, D. C.
Melloh, C. I., Mitchellville, Iowa
McNicol, R. W. E., Physics Department, University of Queensland, Brisbane, Queensland, Australia
Marshall, G. K., 4253 Beaconsfield Ave., Montreal, Que., Canada
Marshall, E. E., 4745 Nevada Ave., Fresno 2, Calif.
Munson, L. A., 1315 Stromeyer Way, Baltimore 24, Md.
Murdock, C. D., 2136 Vendome Ave., Apt. 11, Montreal, Que., Canada
Neil, C. L., 47 Moore Ter., West Orange, N. J.
Norde, L., 43 Maple Ave., East Hempstead, L. I., N. Y.
O'Hare, E. F., 1411 Greenleaf Ave., Chicago 26, Ill.
Ostrom, C. W., 6003 Corliss Ave., Seattle 3, Wash.
Palmer, J. R. B., c/o Iraq Petroleum Company, Haifa, Palestine
Peters, R., 387 State St., North Adams, Mass.
Petrides, T., St. Helena Detail, Receiving Station, South Annex, Norfolk 11, Va.
Plass, H. J., 221 Woodlawn Ter., Collingswood, N. J.
Polk, L. O., A and R Department, Naval Air Station, Alameda, Calif.
Porter, V. J., 6166 N. 17 St., Philadelphia 41, Pa.
Prakash, C., c/o Lloyds Bank, Ltd., Tottenham Ct. Rd., London, W.C.1., England
Praschan, V. E., Fairhaven Apts., 1727 S. Vermont Ave., Los Angeles 6, Calif.
Reed, J. R., Jr., 10 Kendall Ave., Pittsburgh 2, Pa.
Richards, E. W., 143 Lexington Ave., New York 16, N. Y.
Romney, E., Research Construction Company, 230 Albany St., Cambridge 39, Mass.
Ronning, H., 2623 N. Kimball Ave., Chicago 47, Ill.
Rosenthal, M. L., 1117 N. Dearborn Pkwy., Chicago 10, Ill.
Royall, N., 3200 Main, Dallas 1, Texas
Rudy, E. W., 5666 N. Ridge, Chicago, Ill.
Seamon, B., Middle St., Wiscasset, Me.
Skolnik, B. J., 5400 Harper Ave., Chicago, Ill.
Slack, S. J., 175 Voorhis Ave., River Edge, N. J.
Slattery, E. A., 253 S. Second Ave., Hughesville, Pa.
Snadyc, A. M., 214 Ackerman Ave., Clifton, N. J.
Steel, G., FM No. 353, c/o BNLO Navy Yard, Philadelphia, Pa.
Stephens, T. C., 209 N. Dodge St., Iowa City, Iowa
Stinson, J. F., 6028—31 N. E., Seattle 5, Wash.
Story, T. H., 2831 Cove Rd., Merchantville, N. J.
Streb, R. J., 701 Elmwood Rd., Baltimore 6, Md.
Strohlein, E. M., 5327 Large St., Philadelphia 24, Pa.
Stuart, R. M., 5 Brandon Rd., Webster, Mass.
Tidball, F. E., 5806—63 Ave., Eastpines, East Riverdale, Md.
Trees, A. E., 543 Fourth Ave., Brooklyn, 15, N. Y.
Tucker, W., 393 Elizabeth Ave., Newark 8, N. J.
Vanular, R. N., 3868 City Hall Ave., Montreal, Que., Canada
Warnick, G. H., 635 W. 170 St., New York 32, N. Y.
Washburn, C. A., 103 Wildwood Dr., Westwood, Mass.
Wells, M. T., A-V (RS) Staff, NAOTC, Naval Air Station, Jacksonville, Fla.
Weidner, R. T., 2339 Liberty St., Allentown, Pa.
White, C. E., c/o Sherron Metallic Corporation, 1201 Flushing Ave., Brooklyn, N. Y.
Williams, C. R., The Parker Pen Company, Janesville, Wis.
Williams, R. E., 2004 Elm Ave., Portsmouth, Va.
Wintle, M. F., 28 College Ave., Grays, Essex, England
Woodley, C. B., 1210 Pine Ave., Montreal, Que., Canada
Wolin, S., 333 Harvard St., Cambridge, Mass.
Yasinsac, A., 335 S. Main St., Chincoteague, Va.



COLLINS AUTOTUNE*

The Key to Precision Control

THE Autotune was conceived and engineered by Collins many years ago. It was the result of a growing dissatisfaction with slow, haphazard methods of tuning radio equipment and a persistent effort to improve them.

What is it? How does it work?

The Collins Autotune head shown above is a mechanical device for turning a control shaft and stopping it precisely at any one of several pre-determined positions.

The Collins Autotune system consists of a number of Autotune heads, all driven by a single electric motor, each quickly and simultaneously repositioning a separate and non-interrelated tuning shaft to new settings chosen in advance by the operator. At the touch of a button or flip of a dial, the Collins transmitter or receiver is thus completely and exactly tuned to the wanted channel in a matter of seconds.

Collins communications equipment, Autotune controlled, was adopted by American Airlines, Braniff Airways, Tropical Radio Telegraph Co. and others long before the war. Reliability has been demonstrated through the years under all service conditions.

The Collins transmitter design and the Autotune have proved so advantageous to the Armed Services that military authorities have requested other large companies, in addition to Collins, to build them. The Collins Radio Company, Cedar Rapids, Iowa.

ARMY E NAVY

COLLINS

*U. S. Patents issued and pending.

YOU are probably voting now for these and other candidates . . . because yours is the big job of knowing the properties of many new materials and the new applications of others.

In designs for tomorrow's radio parts and cabinets, in electronic equipment now winning the war, in pre-war radios, Masonite* Presdwoods appear in astonishing versatility.

Presdwoods by Masonite are ligno-cellulose hardboards made from exploded wood. This grainless material has been used for chassis plates and parts for speakers, baffles, aerial supports, turn tables, copper clad shield panels for field transmitters and for cabinets.

Specific new uses naturally get no publicity. But when you realize that the Presdwoods are a basic commodity—awaiting your orders for future uses, then you may wish to join those who are making Masonite Presdwoods do industrial jobs better.

These are some of the properties and characteristics of Masonite Presdwoods:

- high structural strength
- moisture resistant
- non-corroding
- smooth, light, thin, hard
- an excellent base for laminated finishes
- provides good bond and surface for all forms of decoration
- may be punched, die-cut or machined
- can be bent into many shapes
- economical

For samples and further information, regarding Masonite Presdwood, write Masonite Corporation, Dept. PI-10, 111 W. Washington St., Chicago 2, Illinois.

*"*Masonite*" *is a trade-mark registered in the U. S. Pat. Off., and signifies that Masonite Corporation is the source of the product.*

MASONITE* CORPORATION

Reg. U. S. Pat. Off.

VACUUM TUBE DESIGNER

An Eastern manufacturer has an attractive opportunity for a graduate physicist or electrical engineer with several years of practical experience in vacuum tube design. It is necessary that applicants have sufficient production experience to develop designs which will improve quality and reduce cost through lowered shrinkage.

Furnish full details regarding experience, education, age, and salary requirements.

Write to: BOX NO. 361

THE INSTITUTE OF RADIO ENGINEERS

330 West 42nd St. New York 18, N.Y.

EXPERIENCED ELECTRICAL ENGINEERS

Graduate or non-graduate Electrical Engineers with at least three years of recent radio circuit or laboratory experience are needed for the development and design of pocket size radio and audio frequency equipment. The company is well established in the electronics field and offers the right man a salary dependent on his experience and also the opportunity to grow in a relatively new field. The company is located in the suburbs of a large New England City.

Write to—

Box no. 358

THE INSTITUTE OF RADIO ENGINEERS

330 West 42nd Street
New York 18, N.Y.

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.
330 West 42nd Street, New York 18, N.Y.

ELECTRONIC ENGINEER

Electronic engineer or physicist for developmental work.

Also, electronic technician for construction work on radio test equipment.

Post-war future in both positions. Write to Premier Crystal Laboratories, 63 Park Row, New York 7, N.Y.

ASSISTANT PROFESSORS

Assistant professors or instructors in electrical engineering to specialize in electronics, communications, and illumination. Strong eastern engineering college. Submit professional record and photograph with application. Positions permanent. Address Box 362.

ELECTRONIC ENGINEERS AND DRAFTSMEN

The services are required of several electronic equipment design engineers capable of supervising the system layout of electronic and electro-mechanical devices.

Also, several draftsmen are needed with experience in electronic schematics, circuit layouts, and wiring diagrams, or with considerable experience in other related electrical fields.

Write giving full qualifications to the Personnel Department, Curtiss-Wright Corp., Development Division, 88 Llewellyn Ave., Bloomfield, N.J.

CONSULTING ENGINEERS

For laboratory with adequate facilities to take on the design of R.F. precision measuring instruments on a contract basis. Send reply to Box 359.

ELECTRONICS ENGINEERS

Development engineers on television and ultra-high-frequency tubes. Technician on tubes. Radio engineers on special applications.

Write full details to Box 363.

ELECTRONIC EXPERT

Needed in management of large New York plant. Capable of supervising manufacture of transmitting and receiving radio assemblies, transformers and other electronic equipment. Excellent opportunity. Write personal and professional qualifications, salary expected, to Box 210, Suite 1024, 122 E. 42 St., New York 17, N.Y.

ELECTRONIC ENGINEER

Radio or electronic engineer for design and development of Army and Navy electronic equipment. Position offers excellent opportunity with well established and expanding company in Connecticut, employing over one hundred personnel. The company's big post-war program in the industrial electronics, radio, and aircraft communications fields assures engineering personnel a continued opportunity for advancement. Address reply to Box 364.

RADIO ENGINEERS, SUPERVISORS AND TECHNICIANS

Chief Radio Engineers, Transmitter and Studio Supervisors and Technicians between thirty and forty-five years of age are needed at once in important war work in the Pacific to construct and operate radio stations. These positions are with the United States Government, with good salaries and subsistence, and for the duration plus six months. Interested persons with actual broadcast experience should write, giving details of radio work, to Box 356.

RADIO, ELECTRICAL AND MECHANICAL ENGINEERS

In the development and production of all types of radio-receiving and low-power transmitting tubes. Excellent post-war opportunities with an established company in a field of opportunities. Apply in person, or write to Personnel Manager of Raytheon Manufacturing Company, 55 Chapel Street, Newton, Mass.

(Continued on page 52A)

ENGINEERS

JUNIORS and SENIORS

For research and Development work in Electronics

EE DEGREE

●

3 to 5 years experience desirable. Excellent opportunity with one of America's Foremost Electronic Laboratories.

●

HAZELTINE CORPORATION
58-25 LITTLE NECK PARKWAY
Little Neck, Long Island, N.Y.

CHIEF BROADCAST RECEIVER ENGINEER

Large eastern radio manufacturer has an opening for a Chief Engineer in its Broadcast Receiver Section. Excellent opportunity for the right person. Must have adequate experience and background. Salary $8,000 to $12,000 per year depending upon ability and experience of applicant.

War Manpower Commission Regulations Apply.

Address all replies to:

BOX NO. 360

THE INSTITUTE OF RADIO ENGINEERS

330 West 42nd St.
New York 18, N.Y.


CHECK TRANSMITTER FREQUENCY IN LESS THAN A MINUTE
THE BROWNING FREQUENCY METER, used by police and other emergency radio facilities for the past five years, is still the best meter for such services — because it was specifically designed for them. The design, which permits determination of any five frequencies from 1.5 to 120 Mc., makes for simplicity of operation which requires less than one minute to check one frequency. All Browning development work aims at specific, rather than broad, uses. Thus, all Browning equipment is best for its particular job. Furthermore, Browning Laboratory facilities are available for study and solution of your own, specific electronic engineering problems. Write for data.
BROWNING
LABORATORIES, INCORPORATED
WINCHESTER, MASSACHUSETTS

POSITIONS OPEN

(Continued from page 50A)

RADIO ENGINEERS

Need radio engineers with experience in Frequency-Modulation transmitting and receiving equipment. Familiarity with F.C.C. rules and field operation of equipment desirable. Send complete experience and education in letter of application, and state salary desired. Company located in the Midwest where living conditions are good, and expenses below average. Address to Box 351.

RADIO ENGINEER

Unusual opportunity for experienced radio engineer. Well established medium-size Midwest radio manufacturer. Large post-war program. Nationally advertised radio line. Write qualifications and experience to the Agency Service Corporation, 66 East South Water Street, Chicago 1, Ill.

VACUUM-TUBE DESIGNERS

Engineers and physicists for research and development work on small vacuum tubes.

An opportunity for post-war employment with a growing organization doing both war and essential civilian production. Recent graduates with adequate training and experienced personnel will be considered for these positions.

Certificate of availability required. Write to Director of Research, Sonotone Corporation, Elmsford, N.Y.

ELECTRICAL ENGINEERS

Needed in connection with the manufacture of a wide variety of new and advanced types of communications equipment and special electronic products. Openings available in St. Paul, Minn., Eau Claire, Wis., and Chicago. Apply or write, giving full qualifications and furnish snapshot, to D. L. R., Employment Department, Western Electric Company, Hawthorne Station, Chicago 23, Illinois.

(Continued on page 54A)

TRANSMITTING TUBES
VACUUM CONDENSERS

HIGH VACUUM CONDENSERS

VC 50 TO 250 give higher efficiency

Photograph shows Jennings Condensers passing through induction heating coils on the automatic rotary high vacuum pumps where the present large production is meeting the exacting requirements of the U. S. Signal Corps Transmitters and the advanced standards of

MODERN ELECTRONIC HEATING EQUIPMENT

Jennings Vacuum Condensers and Transmitting Tubes are used in many critical communication operations in all theatres of war. In the South Pacific where dampness and tropical heat cause corrosion and deterioration, Jennings Vacuum Condensers are helping the Signal Corps **TROPICALIZE*** their Transmitting Equipment. Electronic Engineers realize the importance of this protection in choosing Jennings Condensers for their transmitters now in development.

* Prevents corrosion and deterioration

TROPICALIZE YOUR EQUIPMENT WITH JENNINGS UNITS

Literature will be sent on request

JENNINGS RADIO MANUFACTURING COMPANY, Dept. P

1098 EAST WILLIAM STREET • SAN JOSE 12 • CALIFORNIA

Design and Development RADIO ENGINEERS WANTED

This laboratory plans to add a number of experienced radio engineers to its staff. Particularly desired are men with advanced radio and television circuit development background.

Openings for recent graduates as student or junior engineers are also available.

Salaries will be commensurate with training and experience. All positions are permanent.

WMC regulations apply.

Make application by letter giving complete details of your qualifications or in person to—

Industry Service Division of
RCA Laboratories
(License Laboratory)
711 Fifth Ave., New York 22, N.Y.

POSITIONS OPEN

(Continued from page 52A)

ELECTRONIC SALES ENGINEERS

Established electronic tube manufacturer, located in Midwest, requires sales engineers to cover Midwest or East Coast. Applicants should have electrical-engineering degree, knowledge of electronic circuits and applications, and ability to contact customers. Excellent wartime and postwar opportunity for the right men. Salary and bonus. Send complete information to Box 346.

ELECTRICAL ENGINEER

Electrical engineer wanted for position of chief of research and development section of a Metropolitan New York division of nationwide manufacturer. Must have a sound educational background and outstanding design experience on light equipment. Salary open. Reply in confidence giving complete personal data, experience résumé, availability for release, etc. to Box 348.

FIELD SERVICE ENGINEERS

For domestic and foreign service. Must possess good knowledge of radio. Essential workers need release. Write to Hazeltine Electronics Corporation, 58-25 Little Neck Pkwy., Little Neck, L.I., N.Y.

AUTO-RADIO-SET DESIGNER

An auto-radio-set design engineer with prewar experience needed immediately for postwar development. Write fully, outlining experience, salary expected, etc. Address your letter to Box 341.

DESIGNER

A central New England manufacturer employing over 1000 people needs draftsman-designer on telephone and signaling (mechanical) apparatus.

Knowledge of die-casting and plastic applications desirable. WMC regulations prevail. Write to Box 339.

(Continued on page 58A)

CHIEF LOUD SPEAKER ENGINEER

The Rola Company, Inc. requires the services of an Engineer who has had several years experience and capable of heading this division.

Present work is on 100% urgent war products.

Excellent post-war opportunity with an outstanding, financially sound, long-established manufacturer of radio loudspeakers and transformers.

This Company now has definite plans for an extensive expansion in its Engineering and Manufacturing Divisions.

Salary open.

Write to
The Rola Company, Inc.
2530 Superior Avenue
Cleveland 14, Ohio

EXCEPTIONAL OPPORTUNITY for Experienced Radio Engineers and Technical Writers

One of America's largest transmitter manufacturers located in the Middle-west has openings on its engineering staff for experienced radio engineers and technical writers. The engineers will be offered an opportunity to work on the most advanced type of military equipment and will participate in extensive post-war development plans. We will be particularly receptive to applications from men experienced in airline radio and railroad communications work.

The technical writers should be experienced in preparing instruction manuscripts to Army and Navy specifications. They will also be required in the post-war period to write similar material for commercial applications and technical copy for trade publications.

Ideal working conditions. Salary rate commensurable with ability. State age, experience, education, and references. Address replies to

Chief Radio Engineer
AIRCRAFT ACCESSORIES CORPORATION, ELECTRONICS DIVISION
Fairfax and Funston Roads, Kansas City, Kansas

ENGINEERS

For Design & Development Radio-Television

Degree in communications engineering or equivalent in radio design essential. Post war permanence assured right men.

Write full qualifications—education, experience and status of availability.

Box No. 353
Proceedings of the I.R.E.
330 West 42nd Street,
New York 18, N.Y.

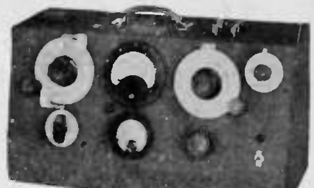
You can depend upon these **DIRECT READING**

INSTRUMENTS

in development, research, design and production of radio and allied equipment

Q-METER

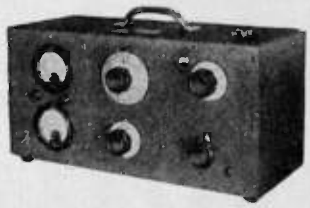
TYPE 160-A



Frequency Range: 50kc. to 75mc. may be extended with external oscillator down to 1 kc.
Range of Q Measurements, Coils: 50 to 625.
Accuracy: In general ± 5%
Range of Q Tuning Condenser: 30-450 mmf. (Vernier Condenser: ± 3 mmf.)

Q-METER

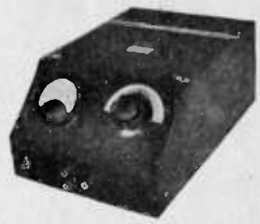
TYPE 170-A



Frequency Range: 30mc. to 200 mc.
Range of Q Measurements, Coils: 100-1200
Accuracy: In general ± 10%
Range of Q Tuning Condenser: 10-60 mmf.

QX CHECKER

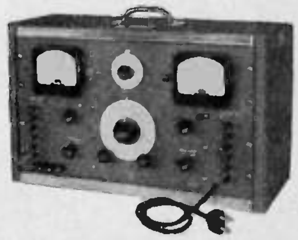
TYPE 110-A



The factory counterpart of the Q-Meter. Compares fundamental characteristics of inductance or capacitance and Q under production line conditions with a high degree of accuracy, yet quickly and simply. Insures uniform parts held within close tolerances. Frequency range 100 kc. to 25 mc.

FREQUENCY MODULATED SIGNAL GENERATOR

TYPE 150 SERIES



Type 150 A—Frequency 41-50 mc. and 1-10 mc.
Type 151 A—Frequency 30-40 mc. and 1-9 mc.
Type 152 A—Frequency 20-28 mc. and 0.5-5 mc.
Type 154 A—Frequency 27-39 mc. and 1-7 mc.
Developed specifically for use in design of F.M. equipment. Frequency and Amplitude Modulation available separately or simultaneously.

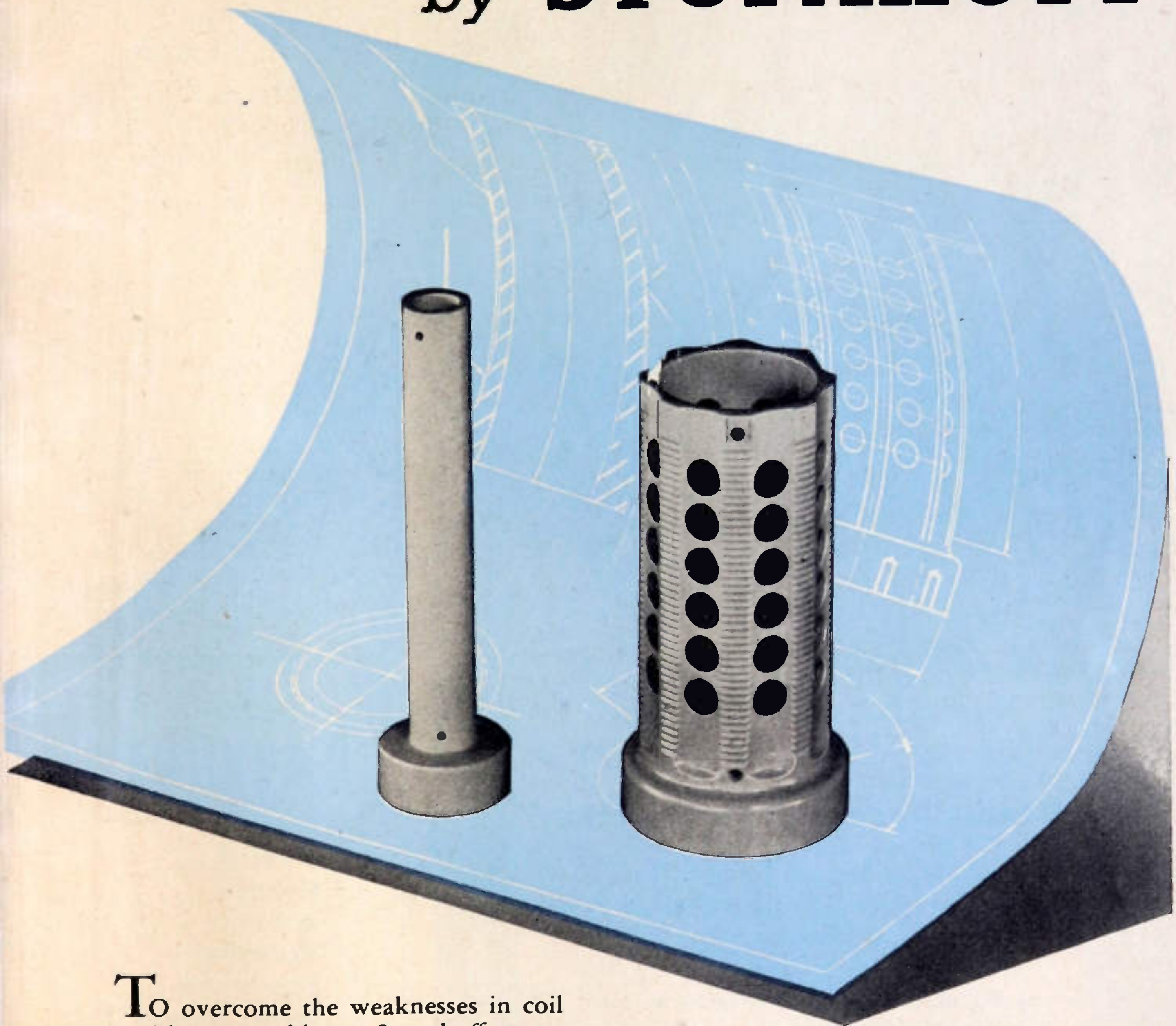
BEAT FREQUENCY GENERATOR

TYPE 140-A

A single compact instrument which provides wide frequency and voltage coverage of generated signals.
Frequency Range: 20 cycles to 5 mc. in two frequency ranges.
Output Voltage Range: 1 millivolt to 32 volts.
Accuracy: ± 3%.
Output Power: One watt into external load.

BOONTON RADIO *Corporation* BOONTON, NEW JERSEY.

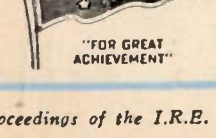
Made in One Piece . . .
by STUPAKOFF



To overcome the weaknesses in coil forms with cemented bases, Stupakoff manufacturing ingenuity has produced single unit construction. The illustrated result — coil forms of optimum mechanical and insulating properties that assure permanence and stability in operation. Vibration and humidity tests prove the superiority of this design.

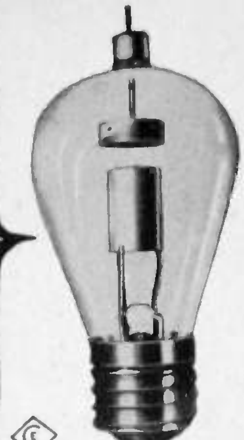
Backed by two generations of experience in the manufacture of precision ceramics, Stupakoff engineers will give dependable assistance in developing insulators for your electronic apparatus. An inquiry will put our technical knowledge and manufacturing facilities at your disposal.

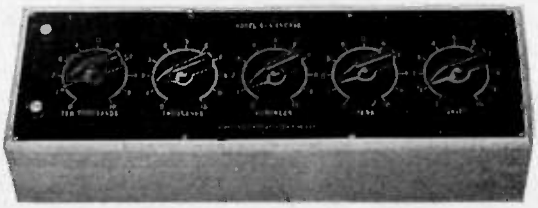
Do More Than Before—Buy EXTRA War Bonds

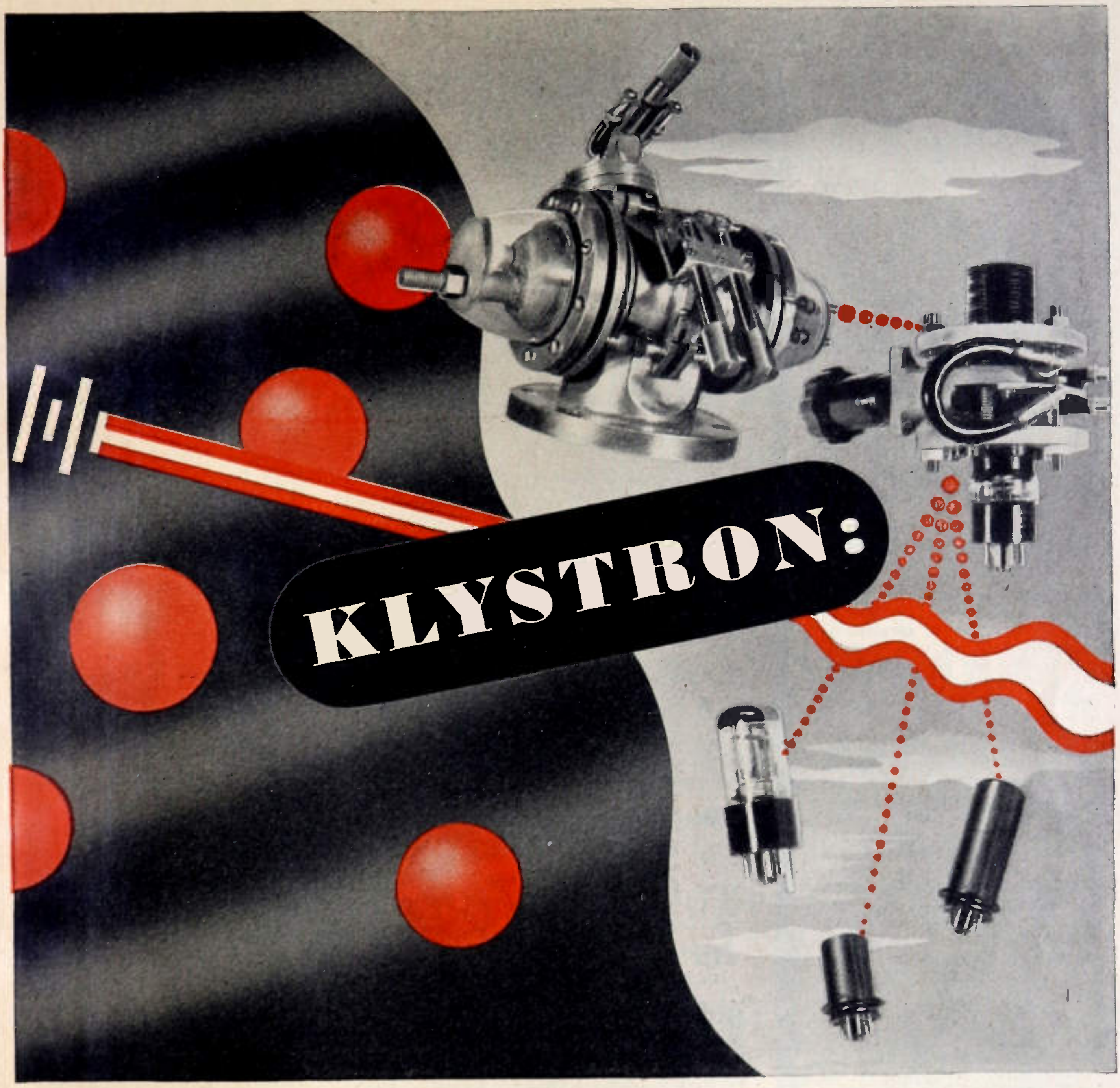


STUPAKOFF CERAMIC AND MANUFACTURING CO., LATROBE, PA.

Ceramics for the World of Electronics







How many Klystrons *are* there?

COMPARED with the early Klystrons which Sperry first developed some years ago, the more recent forms represent dramatic improvements in both size and performance.

And this is only the beginning!

Information on the newer types is presently restricted to those qualified under Military regulations.

But Sperry Klystrons are in use on many battle fronts, and in many applications . . .

There are small Klystrons, and large ones . . . low-powered ones and high-powered ones. There are Klystrons which generate, amplify, and multiply. Where required, frequency stability (better than that required for broadcast purposes) is readily applied by conventional means.

Klystrons are easily modulated for new and all conventional purposes. And, by means of a single knob, they can be tuned continuously over a wide band, or the operator can snap-tune them to previously selected bands.

Write us for further information.

Sperry Gyroscope Company INC.

GREAT NECK, N. Y. • DIVISION OF THE SPERRY CORPORATION

GYROSCOPICS • ELECTRONICS • RADAR • AUTOMATIC COMPUTATION • SERVO-MECHANISMS

PRODUCTS OF MERIT SHARE IN THIS RECOGNITION—

Merit Coil and Transformer Corporation is proud of this U.S. Navy Certificate of Achievement, awarded to us as part of Radar-Radio Industries of Chicago, Inc.

With highly skilled workers and the most modern equipment for manufacturing in accordance with the latest trends in radar-radio production and assembly, Merit has specialized in specific transformer applications for widely varying fields, climates and altitudes.

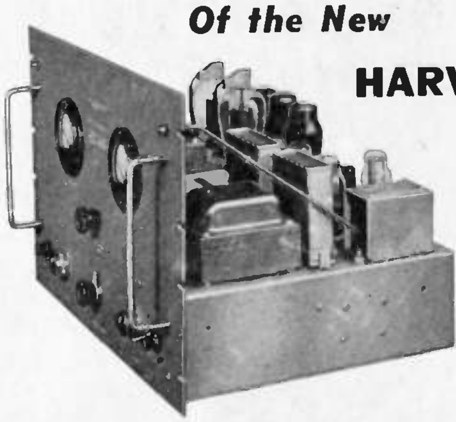
These same facilities and broad experience are available now for development of your post-war products.

Your inquiries will have prompt attention.

MERIT COIL & TRANSFORMER CORP.
4427 North Clark St. CHICAGO 40, ILL.

FIRST OFFICIAL PICTURE

Of the New



HARVEY REGULATED POWER SUPPLY 206 PA

RANGE 500 to 1000 VOLTS

Look It Over! You'll see the quality craftsmanship and compact construction of this new HARVEY 206 PA—its sound design, precision assembly and easy accessibility. Notice the gray, crackle-finish panel and the copper plated chassis.

The new Harvey 206 PA is equipped with spare fuses, a generous 6 ft. heavy duty Typex cord, two interlocks for safety, overload and time delay relays—everything to make it a thoroughly dependable, easy-to-operate source of laboratory D.C. power.

Although the picture gives you an indication of why the HARVEY 206 PA operates smoothly and efficiently, it can't show you how this precision instrument operates in two ranges—500 to 700 volts at 1/4 of an ampere; 700 to 1000 volts at .2 of an ampere—with both ranges accurately regulated within one per cent. That's up to the instrument and us. We'd like nothing better than the chance to show you just what this important new development can do. Get in touch with

HARVEY OF CAMBRIDGE

HARVEY RADIO LABORATORIES, INC.
447 CONCORD AVENUE CAMBRIDGE 38, MASSACHUSETTS

RADIO PARTS OF "TAYLOR LAMINATED PLASTICS"

Many of the problems encountered

* * *

DAILY by radio engineers can best

* * *

be solved by Phenol Fibre,

* * *

or Vulcanized Fibre, in rods, sheets,

* * *

tubes or Fabricated Parts.

* * *

Problems of high dielectric strength,

* * *

light weight, or MASS *production at*

* * *

economical cost are "duck soup"

* * *

to US. *Send us your blueprints, tell*

* * *

us what physical properties are

* * *

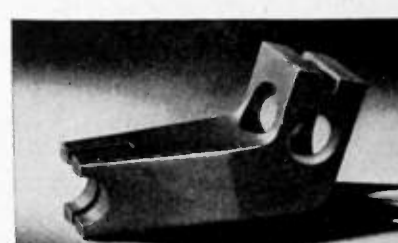
required, and we'll quickly tell you

* * *

whether Laminated Plastics can

* * *

serve you economically and well.



If you think of Phenol Fibre as a plastic that can be used only for the simpler types of insulation, look at this high-finished radio slider that is drilled, slotted, and beveled into just about as complicated a piece of equipment as you'll find in any electrical device. Taylor ingenuity and Taylor equipment turn out such pieces by the thousands at remarkably low cost. Before you decide "it can't be done," Take it to Taylor.

TAYLOR FIBRE COMPANY

LAMINATED PLASTICS: PHENOL FIBRE · VULCANIZED FIBRE
Sheets, Rods, Tubes, and Fabricated Parts
NORRISTOWN, PENNSYLVANIA
OFFICES IN PRINCIPAL CITIES
Pacific Coast Headquarters:
544 S. SAN PEDRO STREET, LOS ANGELES

...WHY AMPEREX

WATER and AIR COOLED TRANSMITTING and RECTIFYING TUBES

AMPEREX

. . . the high performance tube

Amperex engineers have made many important contributions to the refinement of electron tubes. One **"Amperextra"** of note is the development of a means of assuring positive contact between the plate and wire support. Varying and unreliable high resistance contacts have been eliminated by **clinching and riveting.** And it is this method of joining the plate and its supports that makes for a steady, constant flow of plate current.

The sum total of all **"Amperextras"** adds up to cost efficiency in broadcasting, industrial, electro-medical and amateur radio applications. An **Amperex** engineer is available for consultation on your present or postwar problems.

AMPEREX ELECTRONIC CORPORATION

ARMY E NAVY

79 WASHINGTON STREET, BROOKLYN 1, NEW YORK
Export Division: 13 E. 40th St., New York 16, N. Y. Cables: "ARLAB"

IN THIS WAR, YOU GIVE WHAT YOU'VE GOT...DONATE A PINT OF BLOOD TO THE RED CROSS TODAY

Sherron Electronics

A manufacturer's engineering service organization offering complete Laboratory and Manufacturing facilities. Electronic Test Equipment and Production Devices developed or built to specifications.

In more and more electronic plants—where the ideal is the standard, Sherron Test Units are standard equipment.

SHERRON METALLIC CORP.
1201 FLUSHING AVENUE BROOKLYN 6, N. Y.

BROADCAST ENGINEERS — POLICE RADIOMEN

Write Now!

—on your phasing and tuning gear problems

• Let us know *now* your requirements and specifications for *phasing and tuning gear* for your directional antenna. Andrew custom built equipment will again become available as soon as Uncle Sam releases our engineering and manufacturing facilities from production for war.

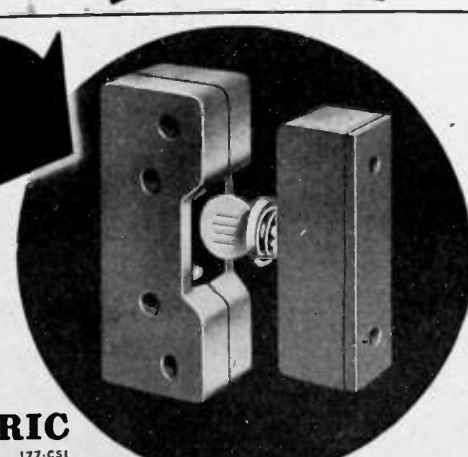
This release may come at any moment. Be sure that your needs are listed at the top of our peace-time back-log. The planning you do now will speed your own reconversion to the new high standards of the future.

Andrew engineers will gladly apply their years of skilled experience to the solution of your special problems in the field of directional antenna equipment:

- Phasing networks and equipment
- Antenna tuning units
- Remote reading antenna ammeters
- Phase monitors
- Coaxial transmission lines and accessories

ANDREW CO.
363 East 75th Street
Chicago 19, Illinois

G-E Safety Door Interlock Switch



OPEN the door and the power's off! Prevents accidents, protects equipment. Will not fail mechanically. For complete details, write:

GENERAL ELECTRIC
177-CSI
ELECTRONICS DEPARTMENT SCHENECTADY, N.Y.

KEY TO Laboratory Standards

Standard Signal Generators
•
Square Wave Generators
•
Vacuum Tube Voltmeters
•
U. H. F. Noisemeters
•
Pulse Generators
•
Moisture Meters
•

MEASUREMENTS CORPORATION
BOONTON, NEW JERSEY

NEW IMPROVED "T"-PAD ATTENUATORS BY TECH LAB

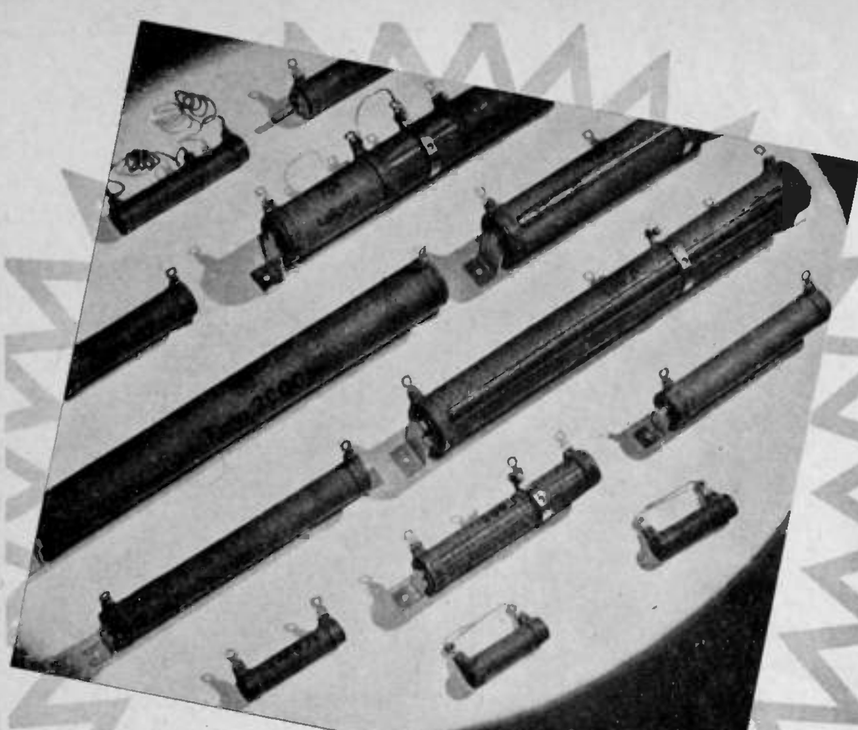
- Stainless Silver Alloy contacts and wiper arms.
- Rotor hub pinned to shaft prevents unauthorized tampering and keeps wiper arms in perfect adjustment.
- Can be furnished in any practical impedance and db. loss per step upon request.
- Write for our Bulletin No. 431.

TECH LAB MICROHMMETER

Direct and instantaneous resistance readings down to 5 microhms and up to 1,000,000 megohms. Write for Bulletin No. 432.

TECH LABORATORIES

7 LINCOLN STREET
JERSEY CITY 7, N. J.



GREENOHMS

ARMY E NAVY

Products of

"THE HOUSE OF RESISTORS"

Standard 10 and 20 watt fixed resistors. 1-50,000 and 1-100,000 ohms.

Standard adjustable resistors. 25 to 200 watts. 1-100,000 ohms. Brackets furnished. Additional sliders available.

Greenohms feature the exclusive Clarostat cold-setting inorganic cement coating. Won't flake, peel, crack, even under serious overload.

Greenohms can take an awful beating. Handle heavy overloads without flinching.

Available in widest range of windings, terminals, mountings, taps, etc., on special order.

★ GREENOHMS—those green-colored cement-coated Clarostat power resistors—definitely "stay put." You can positively bank on their resistance value. Proof? The fact that they are now found in the finest assemblies—quality instruments, radio transmitters, electronic equipment. The resistance is *right* to start with. And it stays *right* even after years of use and abuse.

Recently we had occasion to check a batch of Greenohms that had been lying around in a warehouse for years—part of one of our radio show displays. Each and every Greenohm checked "right on the nose." And they make out even better in use and under real abuse.

★ Submit Your Problem . . .

Tell us about your resistance or control problem. Let us provide engineering collaboration, specifications, quotations.

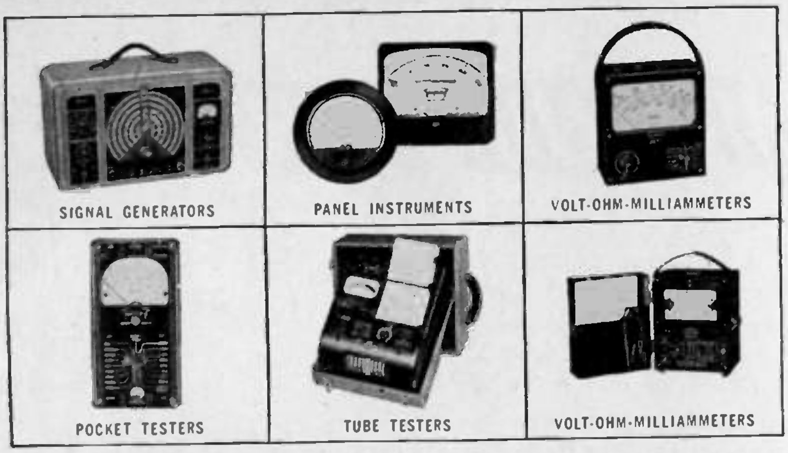
CLAROSTAT *Controls and Resistors*

CLAROSTAT MFG. CO., Inc. · 285-7 N. 6th St., Brooklyn, N. Y.

INDEX

DISPLAY ADVERTISERS

What will you need...
IN THE FIRST SIX POST-WAR MONTHS



✓ CHECK THE TYPES AND QUANTITY

Estimate your future equipment needs and place a *tentative post-war order* for them with your jobber now. This foresight will enable him to stock the Triplett instruments you will need, and will assure you quicker resumption of civilian business. Give best priority you can obtain to facilitate deliveries as production is available.

Get the complete list of Triplett instruments and radio test equipment.

STANDARDS ARE SET BY TRIPLETT

Triplett

ELECTRICAL INSTRUMENT CO. BLUFFTON, OHIO

Platinum metals scrap and residues refined and reworked on toll charges; or purchased outright by us . . .

Write for list of Products. Discussion of technical problems invited . . . .

SIGMUND COHN & CO.
44 GOLD ST. NEW YORK
SINCE 1901

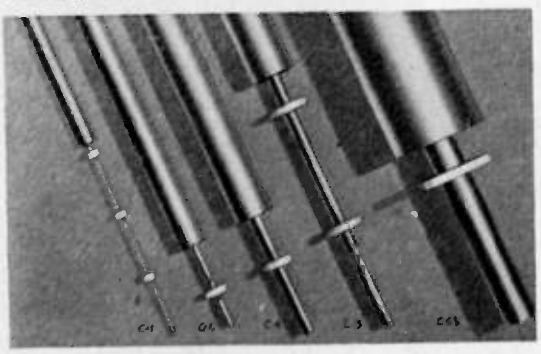
Concentric Transmission Line

by Doolittle

A Standard Product Since 1934

• Ten years of experience in building concentric transmission line and associated impedance matching equipment assures you highest quality and workmanship.

Doolittle lines are made in seven standard sizes. Each line uses seamless copper tubing for the outer and inner conductor, except Types C-1 and C-6 which use solid inner conductors. The insulating heads are made of low loss ceramic—impervious to moisture—spaced and fastened securely for maintaining proper electrical and mechanical characteristics.



Carefully designed fittings and accessories for any requirements are also available.

Special sizes are made to order. For engineering information concerning installation and use, feel free to consult our engineering staff.

WRITE FOR CATALOG AND PRICES

QUICK DELIVERY
On All Standard Sizes Upon Suitable Priority

Doolittle RADIO, INC.
Builders of Precision Communications Equipment
7421 SOUTH LOOMIS BLVD., CHICAGO 36, ILLINOIS

YOURS ..FOR THE ASKING

Available from local dealers or by writing factory direct.

UNIVERSAL STROBOSCOPE

This handy phonograph turntable speed indicator, complete with instructive folder, is now available gratis to all phonograph and recorder owners through their local dealers and jobbers. As a recorder aid the Universal Stroboscope will assist in maintaining pre-war quality of recording and reproducing equipment in true pitch and tempo.

Universal Microphone Co., pioneer manufacturers of microphones and home recording components as well as Professional Recording Studio Equipment, takes this means of rendering a service to the owners of phonograph and recording equipment. After victory is ours—dealer shelves will again stock the many new Universal recording components you have been waiting for.

UNIVERSAL MICROPHONE CO.
INGLEWOOD, CALIFORNIA

TRANSMITTERS for WORLD-WIDE SERVICE

—Powered by RCA

● RCA aviation radio engineering has long been international. All over the world airport control towers and ground stations powered with RCA Transmitters are directing plane traffic, operating radio ranges, communicating with other airports—even in some cases providing shore-to-ship service, or furnishing inter-city telephone facilities—and carrying on other routine and emergency services.

Experience gained in world-wide service and constant research are reflected in the six new RCA Transmitter designs illustrated here.

Covering a wide range of frequencies and power, these transmitters will provide reliable operation for your service—whether you need low or high power, low or high frequency, there is an RCA Transmitter to fit your requirements. Check the features against your needs and write us for descriptive data.

1919 RCA 1944

25 Years of Progress In Radio and Electronics

RADIO CORPORATION OF AMERICA

RCA VICTOR DIVISION • CAMDEN, N. J.

In Canada

RCA VICTOR COMPANY LIMITED, Montreal

TRANSMITTER TYPE ET-4336-C

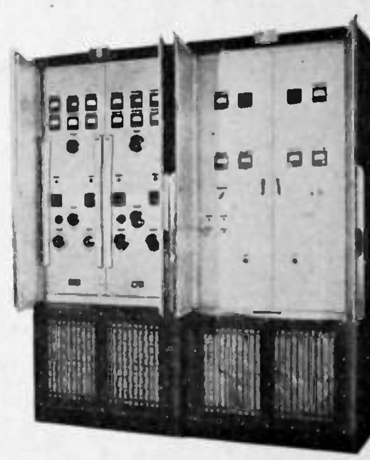
Frequency Range..........2000 to 20,000 kc.
Oscillator Circuit . Crystal
Power Output..............250 watts Telephone
350 watts Telegraph
No. of RF Channels . One
No. of Frequencies . . One
Vertical chassis construction. Built-in modulation indicator. Separate speech amplifier.

TRANSMITTER TYPE ET-4335-LF

Frequency Range................150 to 600 kc.
Oscillator.......Crystal
Power Output.............250 watts Telephone
350 watts Telegraph
No. of RF Channels . One
No. of Frequencies . . One
Modulation indicator and tuning controls on front panel. Built-in speech amplifier, modulator and power supply.

TRANSMITTER TYPE AVT-22B

Frequency Range...........2650 to 19,000 kc.
Oscillator Circuit...............Crystal or M.O.
No. of Channels.............(Two pictured) May be added as desired
No. of Frequencies.............One per channel
Power Output. 5 kilowatts
Type of Emission.........Telephone or Telegraph
Additional channels may be added as required. Master oscillator available as accessory equipment.

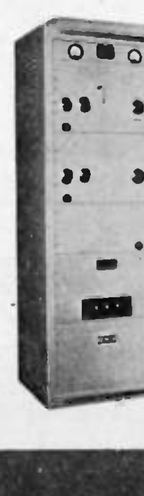


TRANSMITTER TYPE ET-4331

Frequency Range...........3000 to 20,000 kc.
Oscillator Circuit . Crystal
No. of RF Channels . One
No. of Frequencies . . . Six
Power Output. 1 kilowatt
Type of Emission...................Telephone
High fidelity with audio substantially flat between 50 and 10,000 cycles. Speech Inverter for security of messages available as accessory equipment.

TRANSMITTER TYPE ET-4339

Frequency Range...........1700 to 20,000 kc.
Oscillator Circuit . Crystal
Power Output . 200 watts
Type of Emission.......Telephone and Telegraph
No. of RF Channels . Two
No. of Frequencies . . Four
Single unit construction. Remote control available as accessory equipment.



TRANSMITTER TYPE ET-4332-A

Frequency Range...........2200 to 20,000 kc.
Oscillator Circuit . Crystal
Power Output.............250 watts Telephone
350 watts Telegraph
No. of RF Channels . One
No. of Frequencies . . One
Vertical chassis construction. Separate speech amplifier.