# COMMUNICATIONS


FEBRUARY

★ RADIO ENGINEERING
★ NEW F-M DETECTING SYSTEM
★ IRE WINTER MEETING REPORT
★ IMPEDANCE TRANSFORMATION
★ VACUUM TUBE CIRCUIT SIGNS
★ AIRCRAFT COMMUNICATIONS

1944

*"Nothing Like Being Rugged, Eh Kid?"*

Our mechanized Army must have brains, but brawn still counts. The big fellow wrestling interminably with 155 millimeter shells serves his greedy howitzer with the broad back developed by endless months of bone-tiring drill.

If it cannot take the jolts, vibrations, concussions, and extreme atmospheric variations of mechanized global war, the best electronic fighting equipment in the world is useless. Hearts of this combat equipment — electronic tubes — have two strikes against them from the start. Inherently delicate and fragile by nature, still they must be as rugged as the men who depend upon them.

Bump, vibration, immersion, life, and other punishing tests prove the mettle of Hytron tubes before they leave the factory. More important still, results of these tests form the basis for continual improvements in construction and processing. Throughout manufacture — in stem, mount, sealing-in, exhaust, aging, basing, and test departments — engineers, foremen, and skilled operators are ceaselessly striving to achieve in Hytron tubes not only the tops in electronic performance, but also the peak of dependable stamina which combat demands.

OLDEST EXCLUSIVE MANUFACTURER OF RADIO RECEIVING TUBES

# HYTRON CORPORATION

ELECTRONIC AND RADIO TUBES

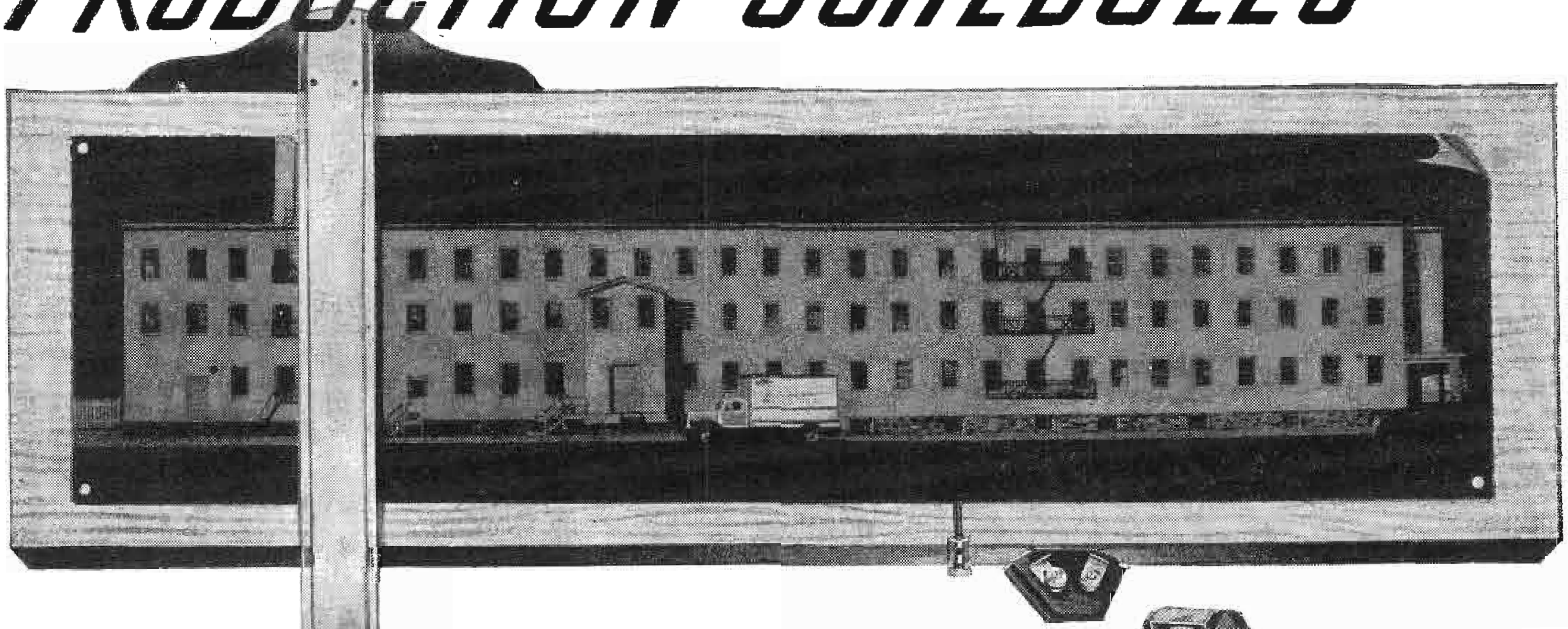
SALEM AND NEWBURYPORT, MASS.

HYTRON RADIO TUBES

BUY ANOTHER WAR BOND

# Designed for *urgent*

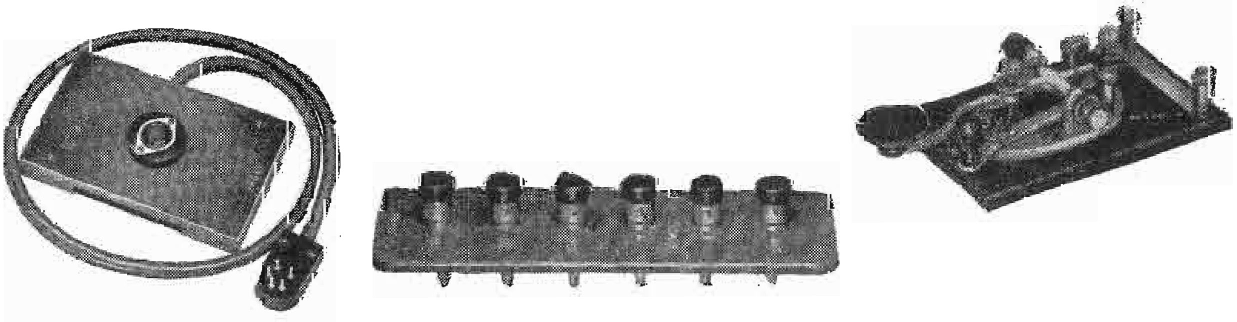
# PRODUCTION SCHEDULES



**THIS** is the new ARHCO plant. Incorporating more than 60,000 square feet of space, it was planned and designed for today's urgent production schedules. Marking another milestone in our successful 21-year growth, it provides even better facilities for research, engineering, manufacturing and delivery.

Out of this new ARHCO plant come over two thousand individual components . . . each one doing a big job in radionic and industrial applications. Moreover, we are equipped to produce special parts from your blueprints. Quotations and advice furnished upon request.

***Put more dollars to work . . . tell the Boys you mean it by buying more War Bonds today***



ARHCO RADIO PRODUCTS

**American Radio Hardware Co., Inc.**

152 MACQUESTEN PARKWAY SOUTH • MT. VERNON, NEW YORK

MANUFACTURERS OF SHORT WAVE • TELEVISION • RADIO • SOUND EQUIPMENT

LEWIS WINNER, Editor
F. WALEN, Assistant Editor
A. D'ATTILIO, Assistant Editor

# *We See . . .*

IN THE POSTWAR ERA OF CHINA, RADIO is destined to become a great industry, according to T. M. Liang of the Chinese Supply Mission. In his recent IRE address, he pointed out that probably a thousand broadcast stations will be required, and a peak output of not less than five-million receivers a year will be necessary. At least nine-thousand marine stations will also be needed, he said.

This tremendous program will require American manpower and materiel help on a vast scale, he emphasized.

In this plea for assistance, he said, "To those of you who in the postwar period will come to China and work with us in the fulfillment of our goal, the rewards will be great. Great not only in the achievement that you will have accomplished, but doubly great in the role you will have played in bringing the light of modern civilization to an aspiring people."

FROM THE MATERIEL COMMAND OF THE AAF in Chicago comes a notice that should be of interest to many. Says the notice . . . "Raw and fabricated materials, standard parts, motors, hardware, fabrics, precision tools, equipment, and other surplus stocks are being offered for sale by the Army Air Forces. Companies interested in such materials, and who are desirous of having their names placed on the active bidders list, are invited to write to the Army Air Forces, Materiel Command, Midcentral Procurement District, 111 West Jackson Boulevard, Chicago 4, Illinois; attention: Redistribution & Salvage Section."

WITH THE ELECTION OF JOHN H. RYAN as NAB president, and the appointment of E. K. Jett as FCC Commissioner, the industry has gained two sterling administrators, who know radio.

Welcome, gentlemen!

IT WILL BE CHICAGO AGAIN FOR THE NAB annual meeting. The place . . . Palmer House . . . and the dates . . . August 28, 29, 30, 31.

# COMMUNICATIONS

Including Television Engineering, Radio Engineering, Communication & Broadcast Engineering, The Broadcast Engineer. Registered U. S. Patent Office.
Member of Audit Bureau of Circulations.

**FEBRUARY, 1944**

**VOLUME 24 NUMBER 2**

**COVER ILLUSTRATION**

Pilot at controls of radio-equipped bomber.
*(Courtesy Western Electric)*



***Published Monthly by the Bryan Davis Publishing Co., Inc.***

BRYAN S. DAVIS, President — PAUL S. WEIL, General Manager
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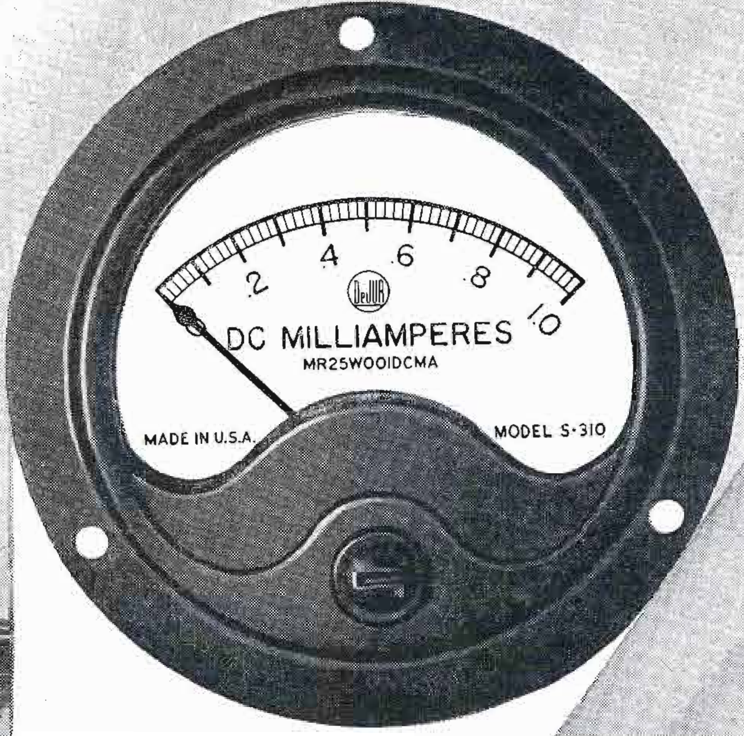
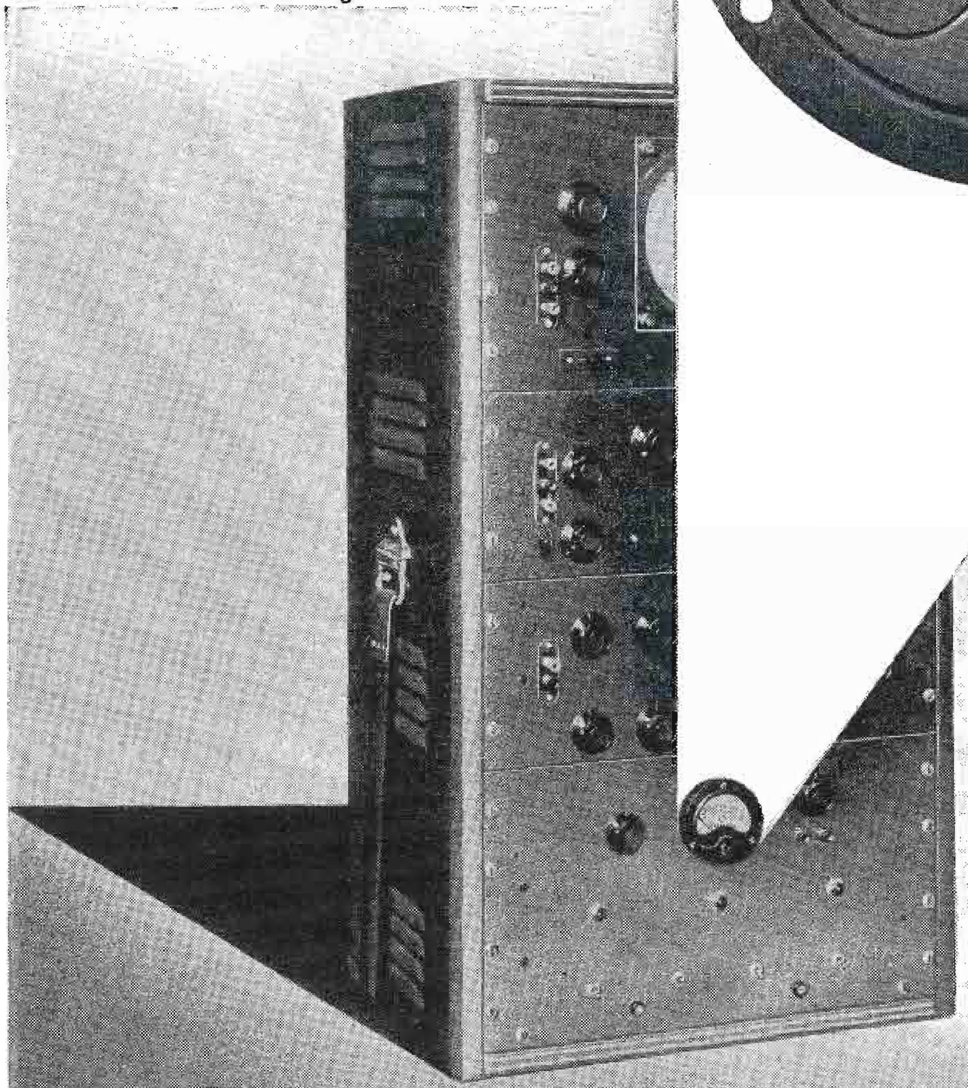
# When building their own testing equipment . . .

Most delicately attuned of all equipment is that used by a manufacturer in testing his products. Many fine names insist upon DeJur precision instruments when building such equipment. For example, the oscilloscope used in the laboratories of the Electronic Corporation of America incorporates one of the various meters bearing the DeJur trademark.



The ECA oscilloscope in which a DeJur instrument is an integral component.

That DeJur instruments are "preferred stock" may be traced to DeJur accuracy, dependability and long life. Refinements in design and construction, growing out of 25 years of distinguished service in the electrical field, give our meters certain definite advantages which become immediately apparent upon application. A DeJur engineer will be glad to assist you . . . whether for your wartime or peacetime program.

AWARDED FOR EXCELLENCE IN PRODUCTION AND QUALITY OF MATERIEL — ARMY E NAVY

**Help Shorten the War . . . Buy More War Bonds**

# DeJur-Amsco Corporation

MANUFACTURERS OF DeJUR METERS, RHEOSTATS, POTENTIOMETERS AND OTHER PRECISION ELECTRONIC COMPONENTS

**SHELTON, CONNECTICUT**

**NEW YORK PLANT:** 99 Hudson Street, New York 13, N. Y. • **CANADIAN SALES OFFICE:** 560 King Street West, Toronto

# *New* INTERNAL-PIVOT PANEL INSTRUMENTS

## 2½-inch—1 inch deep

For radio and other communications service: Type DW-51 d-c voltmeters, ammeters, milliammeters, and microammeters; Type DW-52 radio-frequency ammeters (a-c thermocouple-type). Cases are brass or molded Textolite.

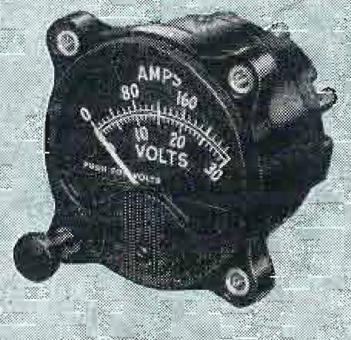
## A New Design That Puts *More* Instrument into *Less* Space

These new, internal-pivot instruments were developed to fill a vital need—particularly in the radio and aircraft fields—the need for compactness. They are *thin*—in most ratings, less than 1 inch deep.

More important is the way their thinness was achieved. In the sketch below, see how the pivots are solidly anchored to the *inside* of the armature shell so they cannot work loose. The moving parts are permanently aligned with stationary parts by bolting the core assembly to a one-piece cast-comol magnet.

Other features are: large-radius pivots, high torque and good damping, lightweight moving element, and ample clearances. Added up, they give you an instrument well able to withstand vibration and hold its rated accuracy, one that is fast on response and easy to read accurately—a design that packs all-round fine performance in a small space.

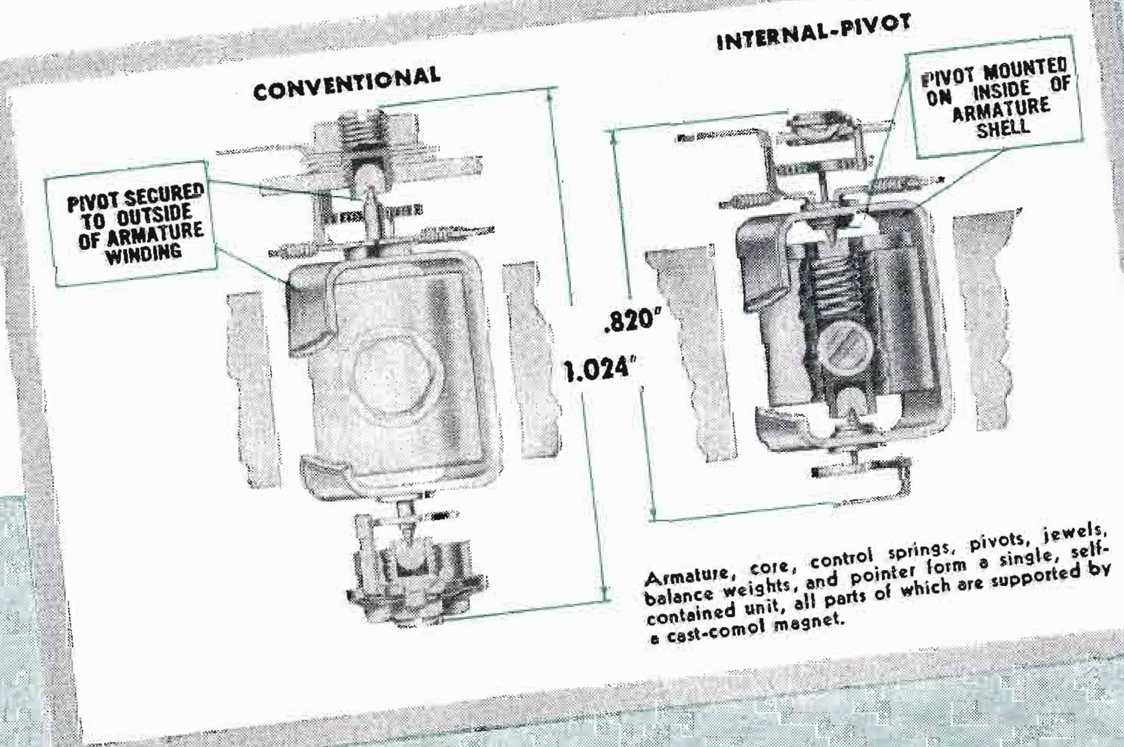
For ratings, price, and dimensions, ask our nearest office for Bulletin GEA-4064, which covers instruments for radio and other communications equipment; or Bulletin GEA-4117, which describes those suitable for naval aircraft. *General Electric Company, Schenectady, N. Y.*




Type DW-53 d-c voltmeters, ammeters, and volt-ammeters that are specially designed to measure voltage and current in battery and battery-charging circuits on naval aircraft. They meet applicable Navy specifications.

*Invest in your future*

*BUY WAR BONDS*




Armature, core, control springs, pivots, jewels, balance weights, and pointer form a single, self-contained unit, all parts of which are supported by a cast-comol magnet.

HEADQUARTERS FOR ELECTRICAL MEASUREMENT

**GENERAL ELECTRIC**

602-56-6210

# "HEY MAC— GET IN ON THIS!"

## *Service Men . . .*

### KEEP SENDING THOSE LETTERS!

**"Bill Halligan says that all the contest entries he's received so far have been *swell*—he wants more letters tellin' about actual experiences with *all* types of Radio Communications equipment built by Hallicrafters including the SCR-299!"**

### RULES FOR THE CONTEST

Hallicrafters will give $100.00 for the best letter received during each of the five months of November, December, January, February and March. (Deadline: Midnite, the last day of each month.)

For every serious letter received Hallicrafters will send $1.00 so even if you do not win a big prize your time will not be in vain.

Your letter will become the property of Hallicrafters and they will have the right to reproduce it in a Hallicrafters advertisement. Write as many letters as you wish. V-Mail letters will do.

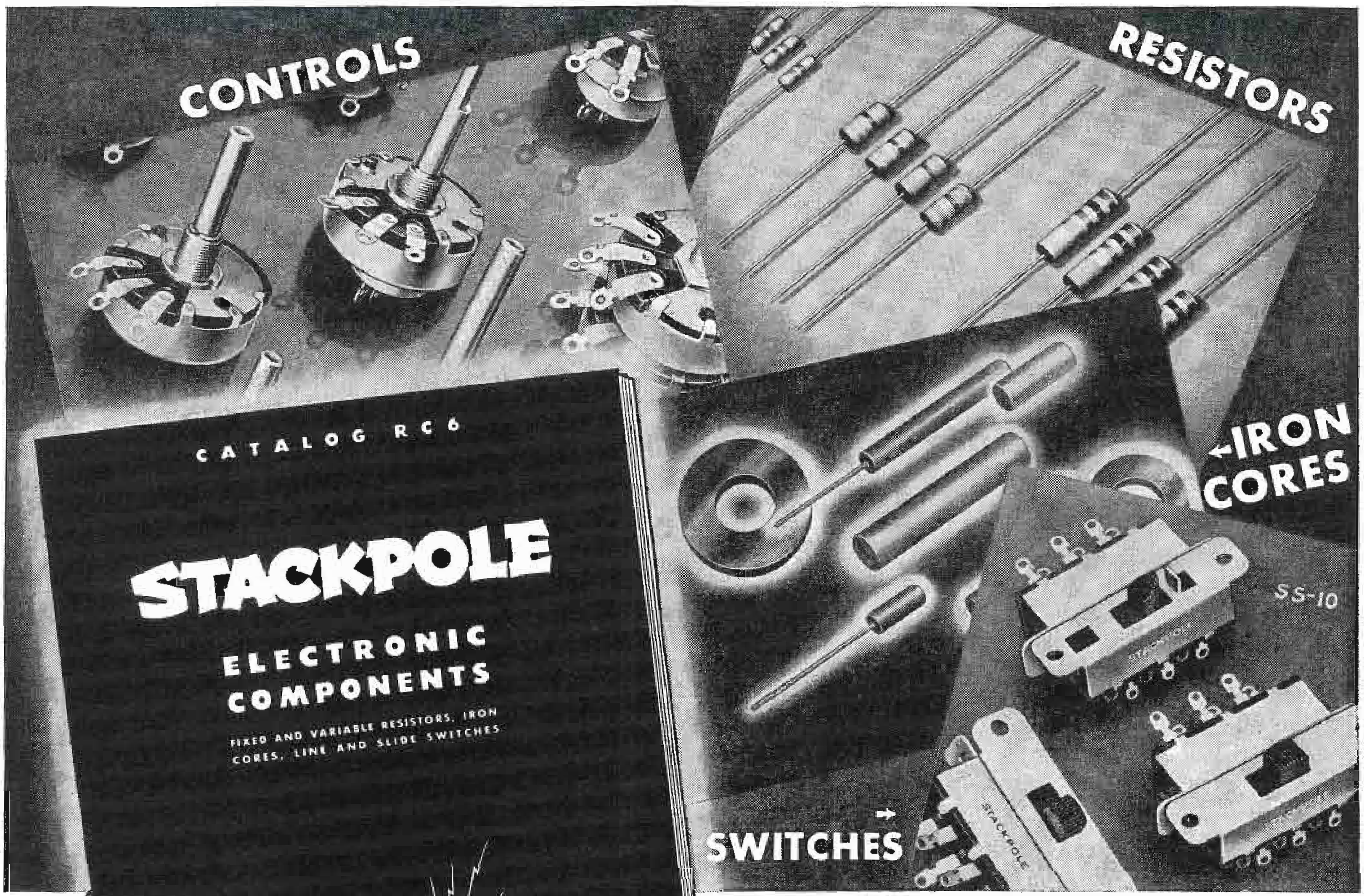
*Military regulations prohibit the publication of winners' names and photos at present . . . monthly winners will be notified immediately upon judging.*

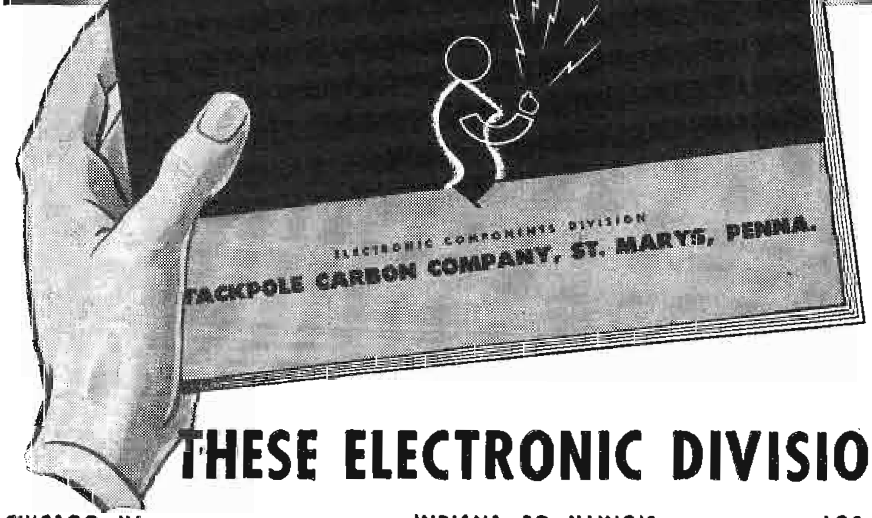
BUY MORE BONDS!

**hallicrafters RADIO**

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

# GET YOUR COPY NOW!




Complete catalog listings, dimension diagrams of every unit, up-to-the-minute engineering data on fixed and variable resistors for radio and other electronic uses, iron cores of all types, and inexpensive slide, line, and rotary-action switches. . . .

That's the story of this new 36-page Stackpole Electronic Components Catalog, just off the press. Write, wire or ask your Stackpole District Engineer for a copy today. Please ask for Catalog R6.

## THESE ELECTRONIC DIVISION ENGINEERS TO SERVE YOU

**CHICAGO, ILL.**
A. A. Woods, 643 Roscoe St.

**CINCINNATI, OHIO**
Wm. C. Laing, 3253 Lambert Place

**DETROIT, MICHIGAN**
J. E. Vollmer, 18310 Pennington Drive

**INDIANA, SO. ILLINOIS and EASTERN IOWA**
C. R. Booth, 540 N. Michigan Ave., Chicago

**KANSAS CITY, MO.**
Maury E. Bettis, Mfr's. Exchange Bldg.

**LOS ANGELES, CALIFORNIA**
H. A. Lasure, 2216 W. 11th St.

**MINNEAPOLIS, MINNESOTA**
J. H. Heimann Company
1218 Harmon Place

**NEW YORK, N. Y.**
Joseph Sprung, 254 W. 31st St.

**PHILADELPHIA, PA.**
J. R. Benge, 6710 Hollis St.

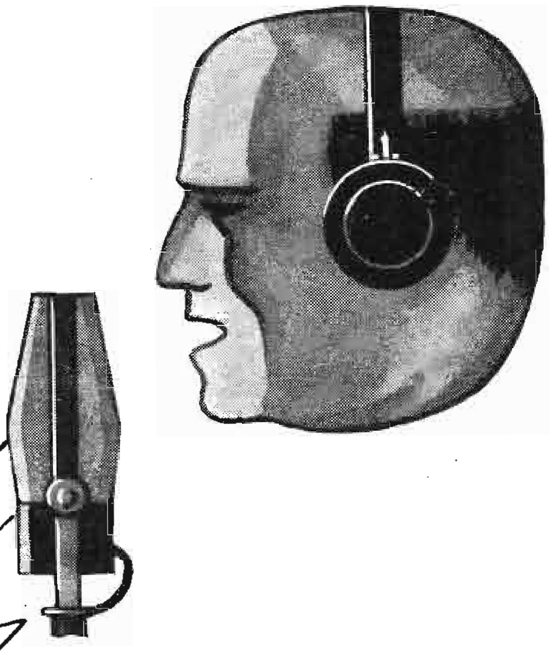
**PLAINVILLE, CONN.**
Karl Dornish, 105 Farmington Ave.

**TORONTO, ONT., CANADA**
A. A. McQueen, 204 King St., East

STACKPOLE CARBON CO., ST. MARYS, PA.

# STACKPOLE

ELECTRONIC COMPONENTS



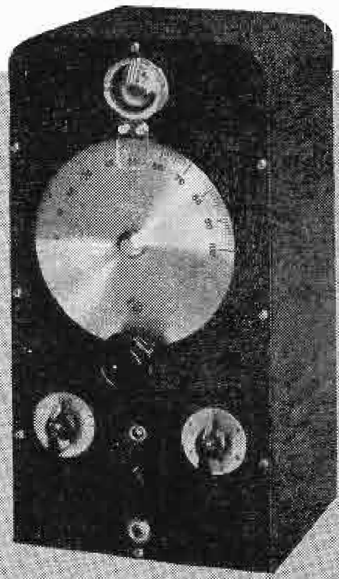
"Calling Car 29 . . . Car 29" **"OK - ON THE WAY!"**

Police radio installations have for some years depended on the Browning Frequency Meter for help in determining the accuracy of fixed-frequency operations. Police departments have found this unit economical to buy, easy to operate, and ruggedly built. Other emergency services have also found this product of Browning Laboratory research to be an asset. Full details are available in literature sent upon request.

Another product of Browning Laboratory research is the balanced-capacitance Browning Signal System for plant protection without armed guard patrols. Descriptive literature is available on request.


# BL BROWNING

**LABORATORIES, INCORPORATED**
**WINCHESTER, MASSACHUSETTS**




JENSEN RADIO MANUFACTURING COMPANY, 6601 S. LARAMIE AVE., CHICAGO 38, U. S. A.

# the amateur is still in radio...

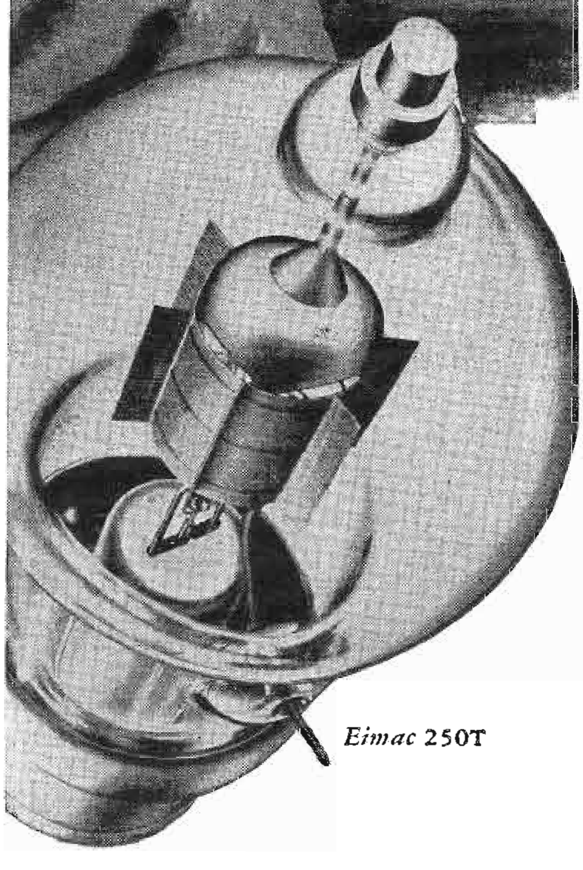
All through the development of radio communications you'll find the mark of the radio amateur. His desire to accomplish the seemingly impossible and the rough treatment he gave his "ham rig" helped create and develop better radio technique. Thus the radio amateur is directly responsible for much of the superior radio and electronic equipment being used by the military services today. Eimac tubes, created and developed in the great amateur testing ground are a good example. They had to possess superior performance capabilities in order to become first choice of the leading radio amateurs.

Their ability to withstand momentary overloads of as much as 600% and their unconditional guarantee against premature failures due to gas released internally are two potent reasons why they are today first choice of the leading electronic engineers throughout the world.

Today the radio amateur is off the air as an amateur but he's still in radio as a professional. And wherever he is ... in the army, navy and marine corps ... in the great electronic laboratories and factories ... he's still using Eimac tubes.

*Follow the leaders to*

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



*Eimac 250T*

**EITEL-McCULLOUGH, Inc., SAN BRUNO, CALIF.**

Plants at: Salt Lake City, Utah and San Bruno, California

*Export Agents: FRAZAR & HANSEN, 301 Clay Street, San Francisco, California, U. S. A.*

748


At war's end, IRC will be prepared to furnish ample quantities of resistors of *all types* to meet Industry's post-war needs.

That these IRC units will be available on a mass production basis is due to the fact that, in meeting war requirements, we have developed the Nation's largest resistor plant using the most improved and efficient types of specialized equipment.

## ENGINEERING HELP FOR YOU

At your service on any resistance problems involved in your peacetime product design plans is our Engineering-Research staff. You may be assured that all projects discussed with this department will be held in strictest confidence.

## FEATURES OF IRC WIRE WOUND POTENTIOMETERS (TYPE W)

**1.** *Tight uniform winding on specially processed bakelite.*

**2.** *Uniform contact pressure which can be adjusted to meet application requirements.*

**3.** *Welded resistance wire terminations.*

**4.** *Only one wiping contact-clock spring between center terminal and contact arm.*

**5.** *Designed for maximum stability under conditions of vibration and shock.*

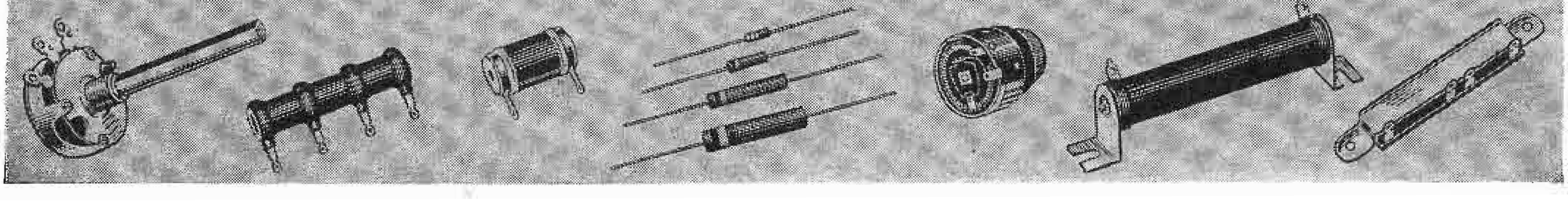
**6.** *Available as duals and triples in combination with composition controls.*

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.**



# IT, TOO, HAS WEIGHT

*That invisible thing called* ***SERVICE***


I N any product, Quality is the first consideration. But beyond that — invisible yet highly important — is *Service.*

The Stewart Line gives you the assurance of outstanding Quality, both in material and fabrication. And, over and above Quality, it gives you a *Service* that interprets and meets your individual needs.

Stewart *Service* is the friendly voice at the other end of your phone. It is the intelligent answer to your inquiry. It is the engineering experience that helps you to work out your problems. It is the co-operation that gets fast action when you are in a jam. Lastly, it is efficiency and promptness in shipping your orders.

Stewart SERVICE—invisible, yet a thing of tremendous weight on the scales of business, particularly under War-time stress—put it to the test!

**STEWART STAMPING COMPANY**

**621 E. 216th Street New York 67, N. Y.**

We carry hundreds of items in stock to meet practically every installation requirement.

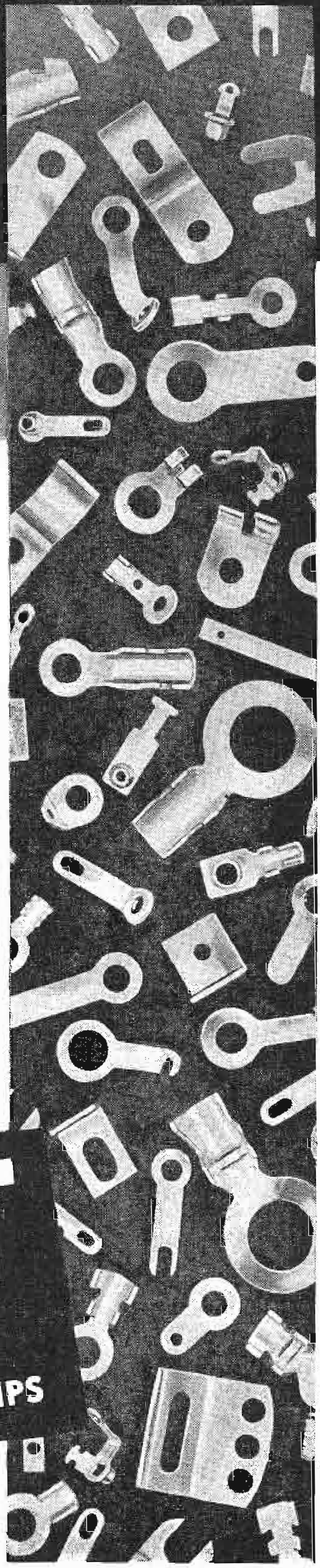
Odd shaped pieces stamped and formed from strip or wire on high speed machines.

Our Tool Room is equipped to make dies for your special needs.

HOT TINNING
NICKEL, CADMIUM,
SILVER AND
ZINC PLATING

*All pieces can be furnished in any desired finish.*

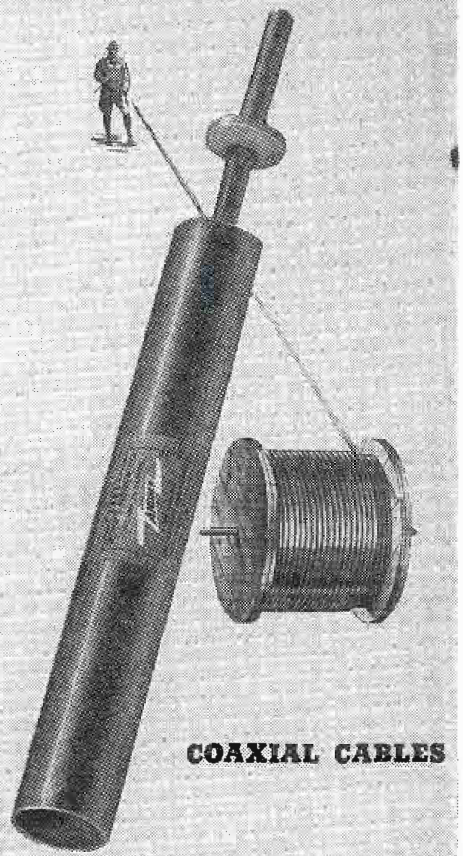
*Send for samples and quotations. Let us have your blue prints and specifications. Quick Response to Inquiries.*



# STEWART

## METAL STAMPINGS

TERMINALS LUGS BRACKETS CLIPS



COAXIAL CABLES

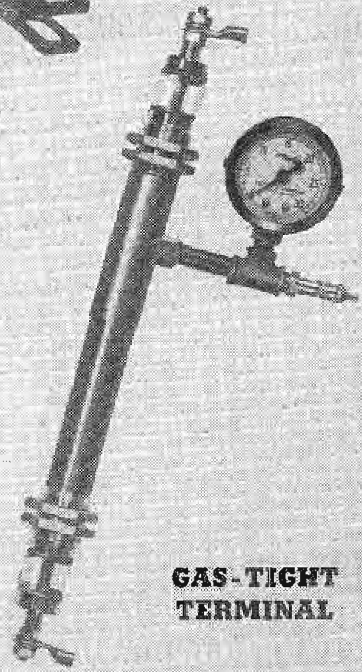
## ANDREW Coaxial Cables for the famous HALLICRAFTERS SCR-299

ANDREW Coaxial Cables are standard equipment on the Hallicrafters-built SCR-299: the mobile communications unit that is doing such an outstanding job on the fighting fronts. It is highly significant that ANDREW Coaxial Cables were chosen as a component of this superb communications unit.

The Andrew Company is a pioneer manufacturer of coaxial cables and accessories. The facilities of the Engineering Department are available to users of radio transmission equipment.

ANDREW
ANDREW CO.

DRY AIR PUMP



GAS-TIGHT TERMINAL

**COAXIAL CABLES.** The Andrew Company is now able to supply standard 70 ohm 7/8" soft temper coaxial cable in lengths up to 4,000 feet! The cable is electrically identical to rigid cables of equal size, but has these extra advantages: the cable may be uncoiled and bent by hand, thus greatly simplifying installation; no connectors, junction boxes or expansion fittings need be installed in the field; thus a big saving is made in installation time and labor.

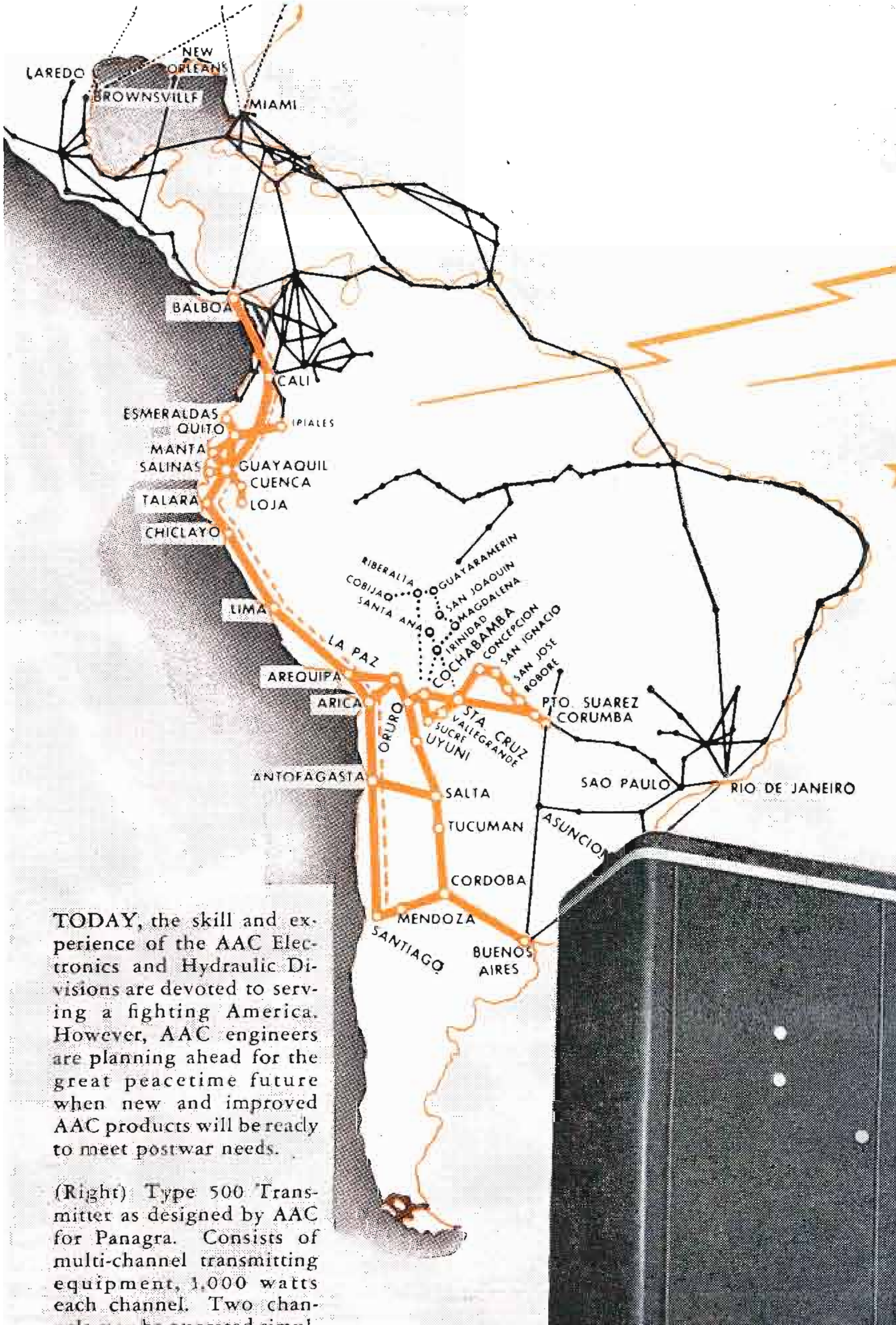
**DRY AIR PUMP.** This hand-operated pump quickly, efficiently and economically dehydrates the air inside coaxial cables, in addition to having a multitude of other applications. It dries about 170 cubic ft. of free air, reducing humidity from 60% to 10%.

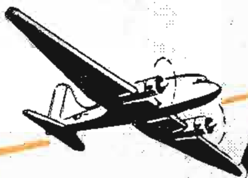
**GAS-TIGHT TERMINAL.** The new Andrew glass insulated terminal is an outstanding development that provides a 100% air-tight, gas-tight system for gas filled coaxial cables. A special design that minimizes shunt capacity makes this terminal ideally suited to high frequency operation.

**COAXIAL ANTENNA.** Suitable for fixed station use and pretuned at the factory to the desired operating frequency, the Andrew type 899 vertical coaxial antenna provides an efficient, easy-to-install, and inexpensive half-wave radiator in the frequency range from 30 to 200 MC. Careful engineering has utilized to the utmost the well known advantages of the coaxial antenna over other types of vertical half-wave antennas.

*CATALOG DESCRIBING COAXIAL CABLES AND ACCESSORIES FREE ON REQUEST.*
*WRITE FOR INFORMATION ON ANTENNAS AND TUNING AND PHASING EQUIPMENT.*

THE ANDREW COMPANY • 363 EAST 75TH STREET • CHICAGO 19, ILLINOIS



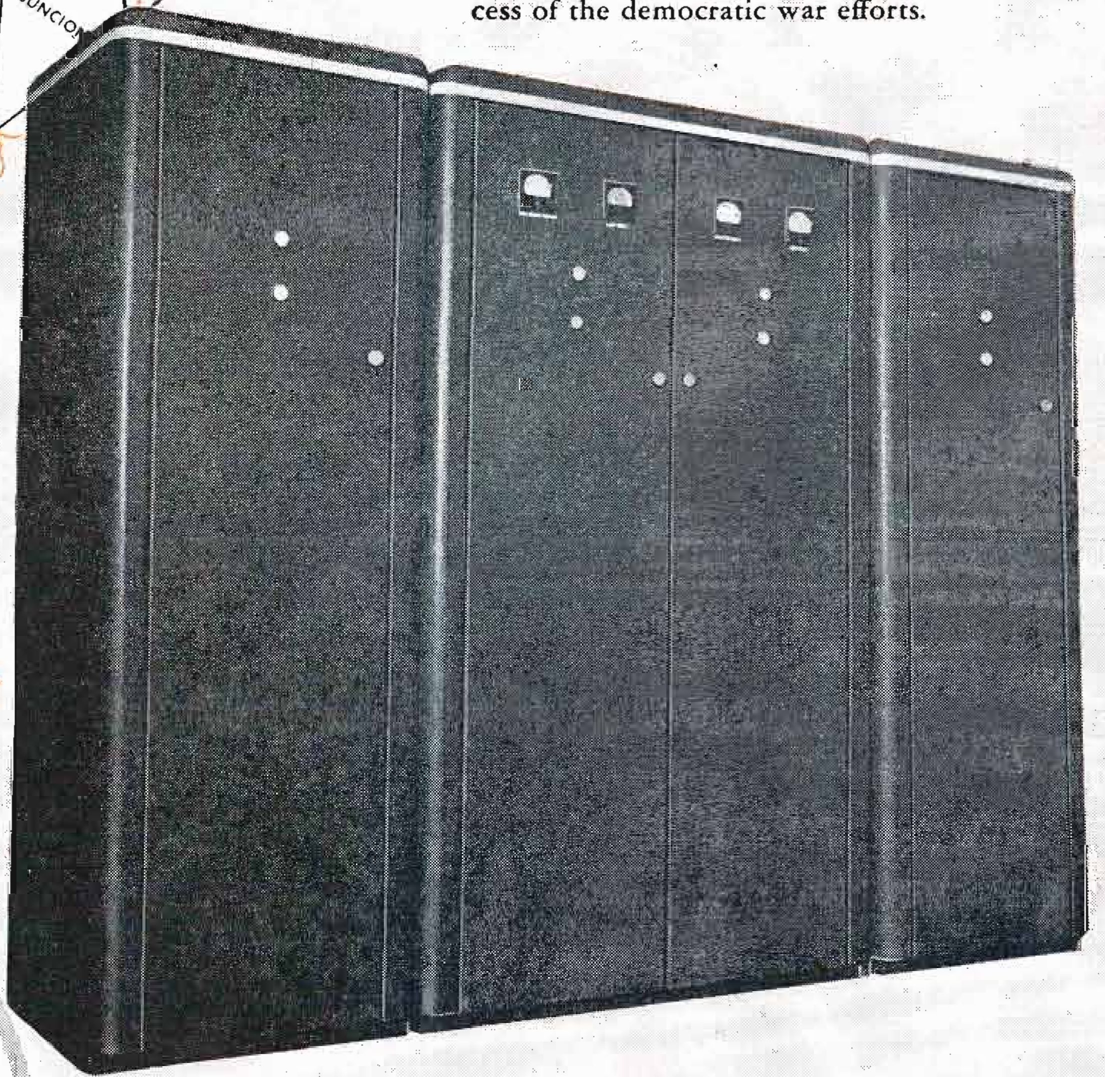
# AAC

★ **ALONG THE PANAGRA ROUTE** is located AAC transmitting equipment at approximately 30 different points in Colombia, Ecuador, Peru, Chile, Bolivia and Argentina—forming the nucleus of the radio navigation and communications system.

Panagra is today primarily devoting its personnel and facilities to maintenance of aerial lifelines between the Americas, across which are speeding men, mail and materials vital to the success of the democratic war efforts.

TODAY, the skill and experience of the AAC Electronics and Hydraulic Divisions are devoted to serving a fighting America. However, AAC engineers are planning ahead for the great peacetime future when new and improved AAC products will be ready to meet postwar needs.

(Right) Type 500 Transmitter as designed by AAC for Panagra. Consists of multi-channel transmitting equipment, 1,000 watts each channel. Two channels may be operated simultaneously. Telephone and telegraph transmission. Frequency range 250-550 KC and 1500-12000 KC.



AAC Products

Randolph C. Walker PRESIDENT

**AIRCRAFT**

**Manufacturers of PRECISION**

**Burbank, Calif. Kansas**

# TRANSMITTERS

## AND OTHER COMMUNICATIONS EQUIPMENT

*for*

## Dependable Operation Of Airlines And Various Communication Services

★ Today, AAC transmitters and other AAC communications equipment play a vital part in dependable operation of warplanes on the fighting fronts, as well as airlines serving the war-busy Americans on the home fronts.

AAC Electronics Division has won distinctive leadership as one of the country's large producers of radio transmitting and receiving equipment. One outstanding example of AAC communications engineering is the equipment designed and built to meet the specified needs of Pan American-Grace Airways, Inc. Consisting of a multi-channel 1,000 watt transmitter, this equipment is used by Panagra for radio homing and communication purposes. It represents one of a complete line of transmitting equipment for use by airlines or services having similar communication needs.

At the present time practically all AAC facilities are devoted to war production. However, your inquiries are welcomed now for commercial equipment which can be supplied in limited quantities if adequate priority ratings are available.

AAC products in transport planes, cargo carriers, troop ships, bombers . . . airport traffic net, police or other services where communications are crucial, can be depended upon as expertly engineered and built to the most efficient performance standards.

*Products of* **ELECTRONICS DIVISION**

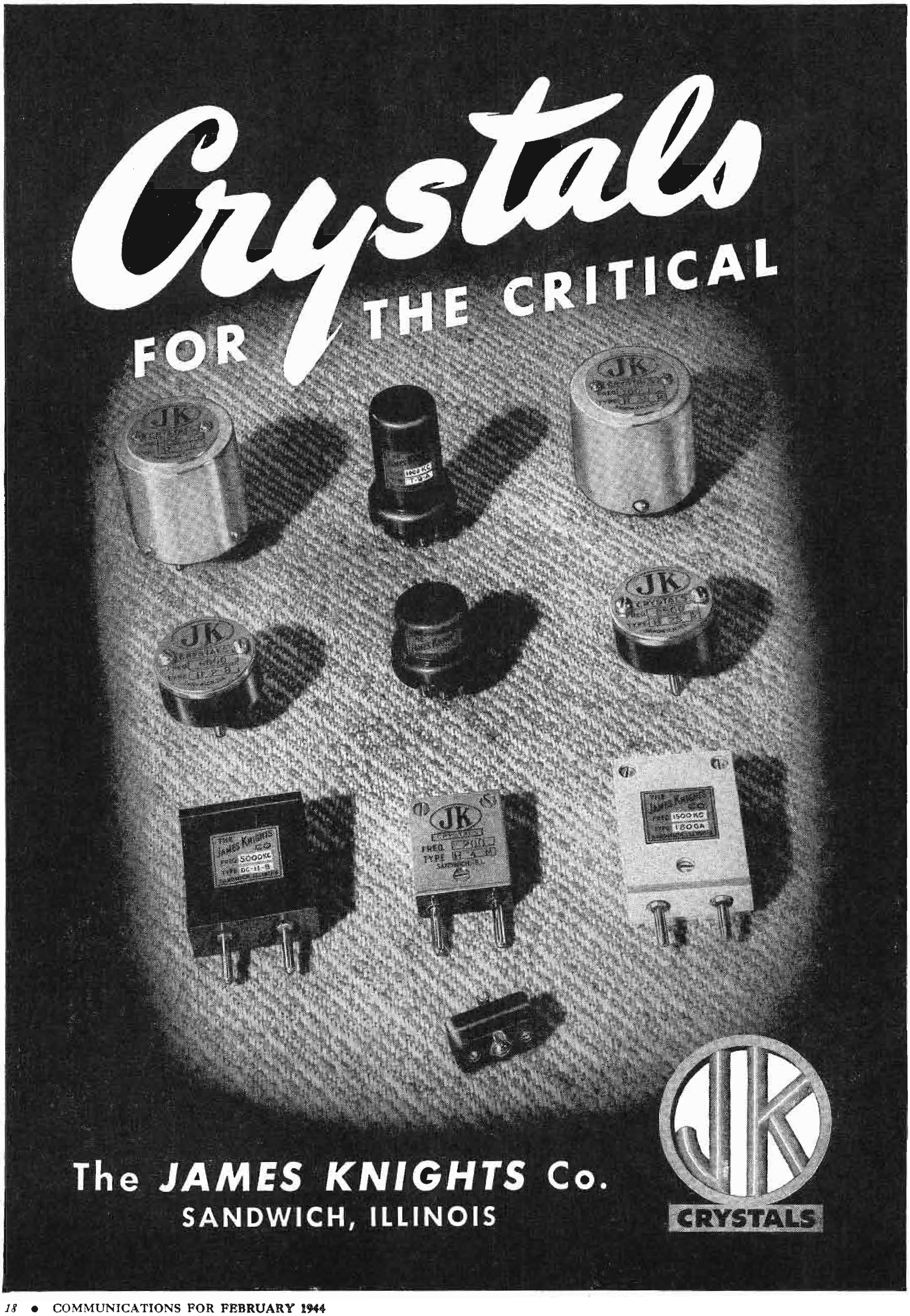
**TRANSMITTERS • AIRCRAFT & TANK ANTENNAS • QUARTZ CRYSTALS • RADIO TEST EQUIPMENT**

(Below) Panagra airliner delivers important cargo of mail and passengers.


# ACCESSORIES CORPORATION

**AIRCRAFT EQUIPMENT • HYDRAULICS • ELECTRONICS**

City, Kans. New York, N. Y. Cable Address: AACPRO


Crystals
FOR THE CRITICAL
The JAMES KNIGHTS Co.
SANDWICH, ILLINOIS
JK
CRYSTALS


**OTHER ORIGINAL ELECTRO-VOICE MICROPHONES SERVE IN EQUALLY VITAL COMMUNICATIONS FUNCTIONS OF OUR WAR PROGRAM.**

**THE DIFFERENTIAL MICROPHONE . . . the famous Model T-45 "Lip Mike" is one of the more recent exclusive Electro-Voice designs, developed in its present form with the close collaboration of the Fort Monmouth Signal Laboratories.**

*Builders of war equipment may secure additional information concerning these and all other. Electro-Voice developments. However, if limited quontity needs may be filled by any of our Standard Model Microphones, with or without minor modifications, we suggest that you contact your local radio parts distributor. His knowledge of our products will be of invaluable aid in helping you solve your problems. He can also be an important factor in expediting smaller orders. NOTE: Any model Electro-Voice Microphone may be submitted to your local supplier for TEST and REPAIR at our factory.*

**Electro-Voice MICROPHONES**

**ELECTRO-VOICE MANUFACTURING CO., INC.**
**1239 South Bend Ave. • South Bend 24, Indiana**
EXPORT DIVISION: 13 EAST 40th ST., NEW YORK 16, N. Y.—U. S. A. CABLES: ARLAB

# *Masterpiece*

## OF SKILLED HANDS

One of the world's masterpieces in marble — "The Kiss", by the celebrated French sculptor, Auguste Rodin (1840-1917), creator of the famed and familiar "The Thinker".

Machines can do almost anything. . . . But it takes *more* than machines to create an electronic tube. . . . A tube may be brilliantly engineered for electronic and mechanical advancements. It may contain the highest quality components. Yet it will be no better in performance than the skill and care of the hands that assembled it. . . . Each tube that leaves the UNITED testing line is an industrial masterpiece. Into its manufacture has been wrought the perfect hand workmanship which is the counterpart of its perfect design.

# UNITED

**ELECTRONICS COMPANY**

NEWARK, 2 New Jersey

*Transmitting Tubes EXCLUSIVELY Since 1934*

ARMY E NAVY


## ...YOUR 4TH WAR LOAN QUOTA

WHETHER your plant meets its quota, or fails, lies largely in *your* hands. Your leadership can put it over—but if you haven't already got a smooth running, hard hitting War Loan Organization at work in your plant, there's not a minute to lose.

Take over the active direction of this drive to meet —*and break*—your plant's quota. And see to it that every one of your associates, from plant superintendent to foreman, goes all-out for Victory!

To meet your plant's quota means that you'll have to hold your present Pay-Roll Deduction Plan payments at their all-time high—plus such additional amounts as your local War Finance Committee has assigned to you. In most cases this will mean the sale of *at least* one $100 bond per worker. It means having a fast-cracking sales organization, geared to reach personally and effectively every individual in your plant. And it means hammering right along until you've reached a 100% record in those *extra* $100 —or better—bonds!

And while you're at it, now's a good time to check those special cases—*growing more numerous every day*—where increased *family* incomes make possible, *and imperative,* far greater than usual investment through your plant's Pay-Roll Deduction Plan. Indeed, so common are the cases of two, three, or even more, wage-earners in a single family, that you'll do well to forget having ever heard of '10%' as a reasonable investment. Why, for thousands of these 'multiple-income' families 10% or 15% represents but a paltry fraction of an investment which should be running at 25%, 50%, or more!

After the way you've gone at your wartime *production* quotas—and topped them every time—you're certainly not going to let anything stand in the way of your plant's breaking its quota for the 4th War Loan! Particularly since all you are being asked to do is to sell your own people the finest investment in the world—*their own share in Victory!*

**LET'S ALL BACK THE ATTACK!**

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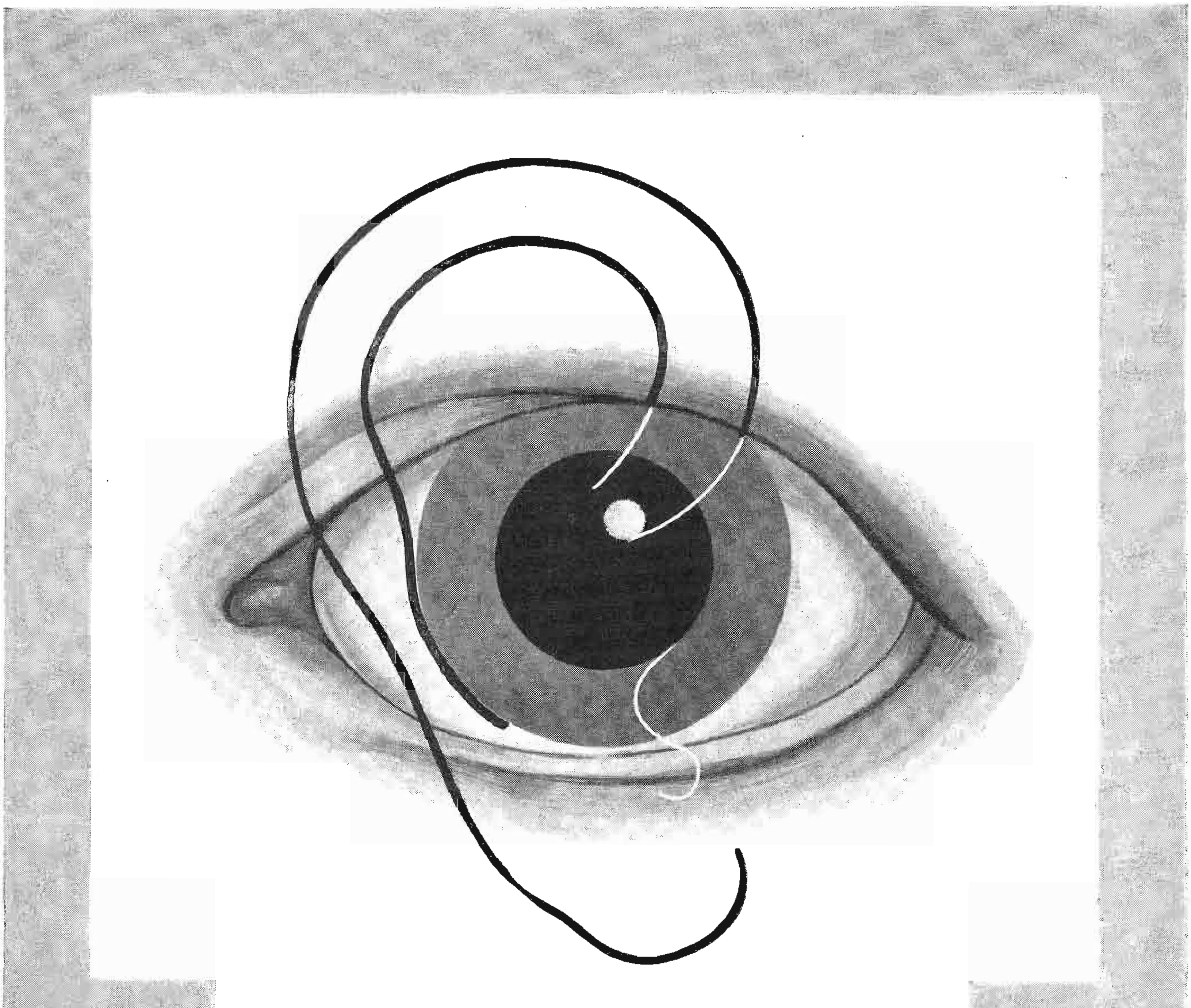


COMMUNICATIONS

LEWIS WINNER, Editor

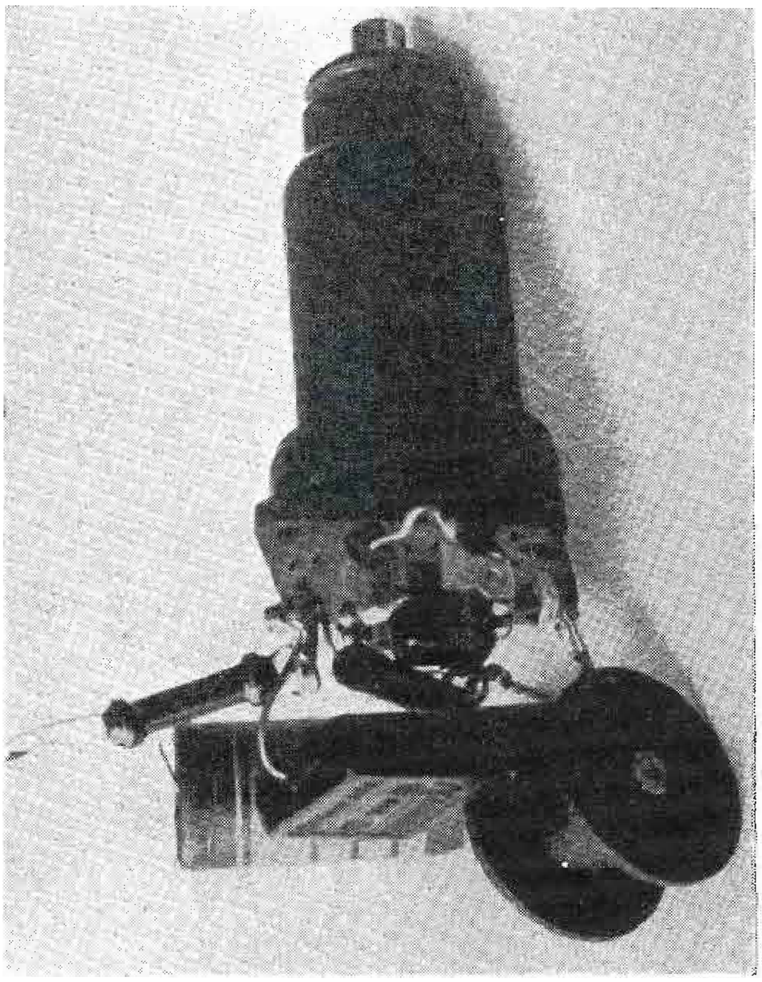
* * FEBRUARY, 1944 * *

# COMBINATION A-M/F-M DETECTOR

## Versatile Limiter-Detector Responding to Either F-M or A-M Signals For Receiving and Transmitting or Control Purposes Where Simplicity, Size, Cost and Absence of Adjustment are Important

by FREDERICK C. EVERETT

Engineer, Radio Facilities Group, NBC



A-M/F-M detector removed from chassis. Cathode coil, plate bypass, diode load resistor, diode bypass and avc resistor are visible.

THE detection of frequency-modulated waves requires an arrangement of tubes and associated equipment that is quite formidable. For we have the limiter, discriminator and associated transformers and networks.

It is true that complexity has not been a deterrent to development and application. However any simplification is desirable, particularly for the combination a-m/f-m receivers that will be made in the future. In addition, system simplification in mobile and portable equipment, where f-m has found wide acceptance, can be helpful too. Size, weight and current drain can thus be controlled more effectively.

A reduction in the components used appears to offer a way to provide such simplification. A system that may represent a step in that direction is presented in this paper. It provides in one tube . . . a duplex diode triode . . . the functions of an a-m detector, f-m detector, limiter, discriminator and in addition, also provides automatic volume control.

### Diode-Triode Detector Circuit

Let us take the diode-triode detector circuit shown in Figure 1 for analysis. Then let us redraw that circuit as shown in Figure 2. If we can cause amplitude modulation to take place in the cathode circuit, we know that the diode will act as a detector of the wave and provide an audio output corresponding to the envelope of the amplitude modulated wave. The triode portion of the tube is shown separately in Figure 3. We see here that the triode is cathode coupled to the diode and that the output voltage which is applied to the diode is $E_k$.

### Equation For Gain

Representing the tube in Figure 4, by the conventional method of substituting a fictitious generator with a voltage $\mu E_g$ and an internal resistance $R_p$, and taking the a-c plate current flowing to the plate, it becomes apparent that the following is true.

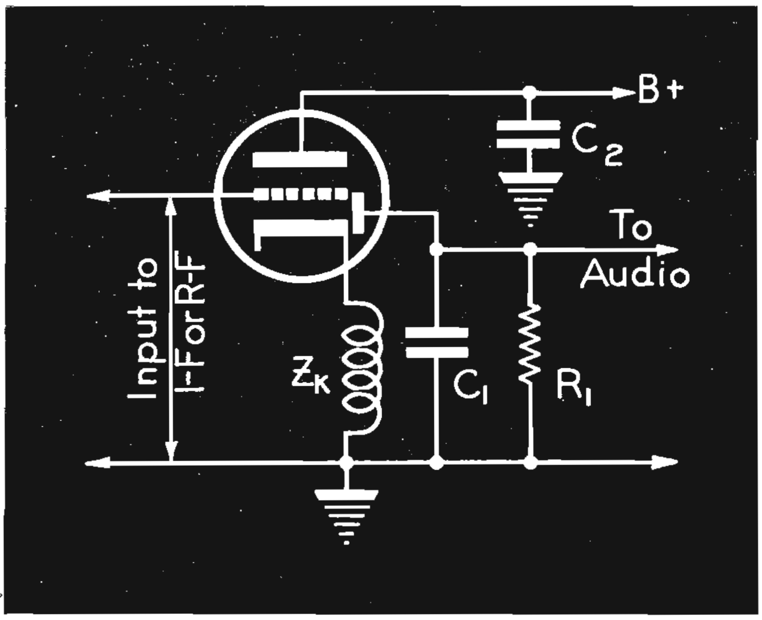
$$E_g = E_i + E_k \qquad (1)$$

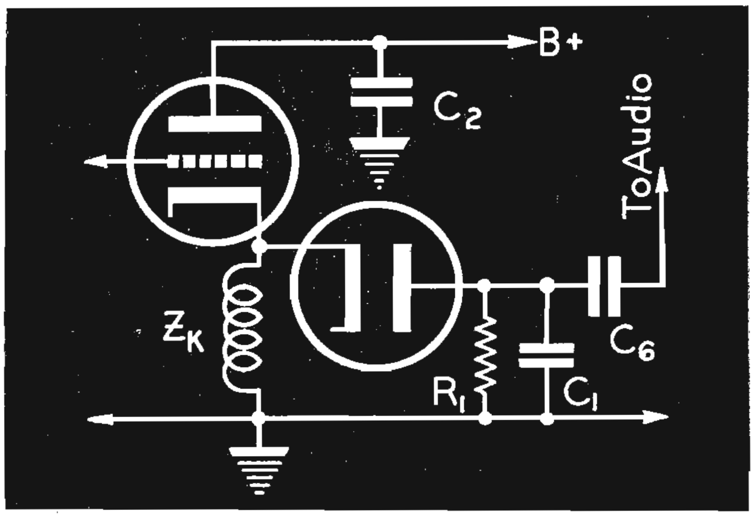
$$E_i = E_g - E_k = E_g - I_p Z_k \qquad (2)$$

$$\text{since } E_k = I_p Z_k \qquad (3)$$

$$\text{and } I_p = \frac{\mu E_g}{R_p + Z_k} \qquad (4)$$

Gain represents the ratio of output




to input voltage. Thus

$$\text{gain} = \frac{E_k}{E_i} = \frac{I_p Z_k}{E_g - I_p Z_k} = \frac{\dfrac{-\mu E_g}{R_p + Z_k} Z_k}{E_g + \dfrac{\mu E_g}{R_p + Z_k} Z_k}$$

$$= -\frac{\mu Z_k}{R_p + Z_k + \mu Z_k}$$

$$= -\frac{\mu Z_k}{R_p + Z_k (1 + \mu)} \qquad (5)^1$$

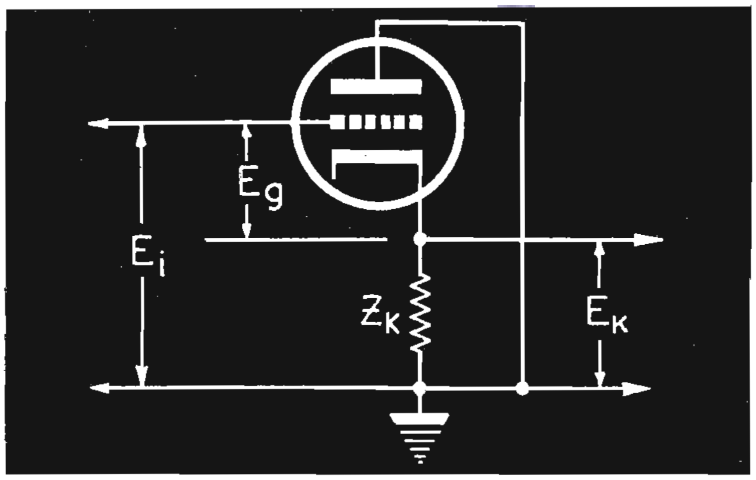
This is the equation for the gain of the cathode-coupled amplifier and is thus shown to approach toward unity if $Z_k$ becomes sufficiently large compared with the plate resistance. It can also be noted that the value of gain changes very slowly with varying values of $Z_k$, (Figure 4a).

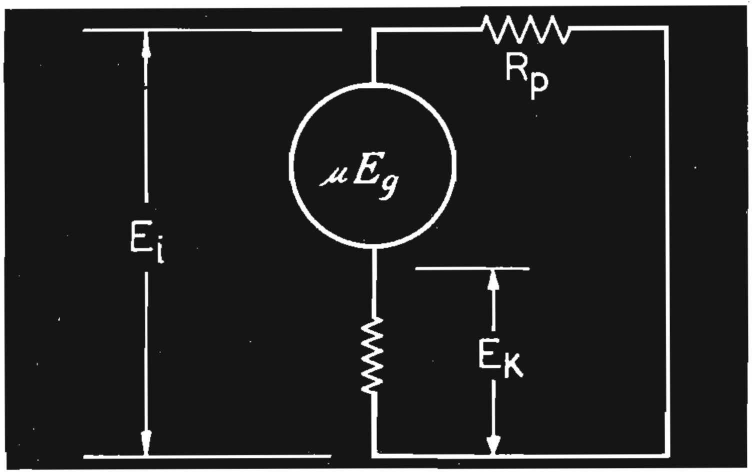
If the tube is operated as a class *A* amplifier with correct grid bias, and the grid is not allowed to swing positive, it is obvious that the above analysis is valid. An inductance is convenient to use as the cathode impedance, since parallel tuning the cathode load to resonance to increase the impedance, will cause very little change in gain. And a resistance here would bias the diode when a common-cathode dual-purpose tube is used.[2]

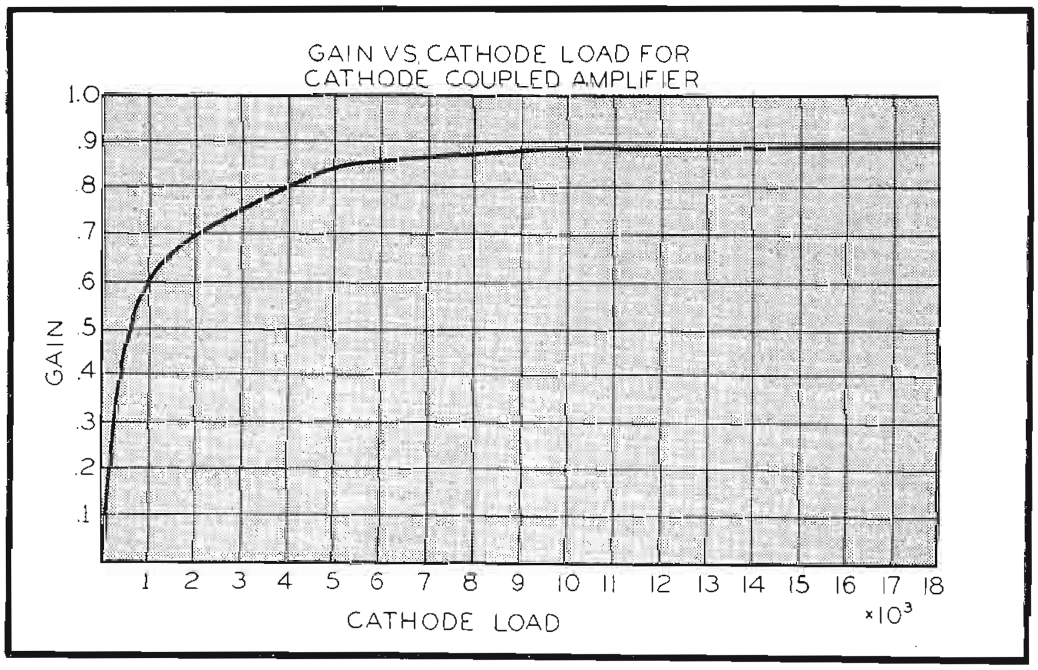
Under these circumstances any amplitude-modulated wave will be repeated in the cathode circuit and detected in the diode circuit, (Figures 1 and 2). The advantage gained over the conventional circuit is lack of loading of the tuned circuit, which provides increased gain and selectivity, attributes often sought after in *communication-type* receivers, at least.

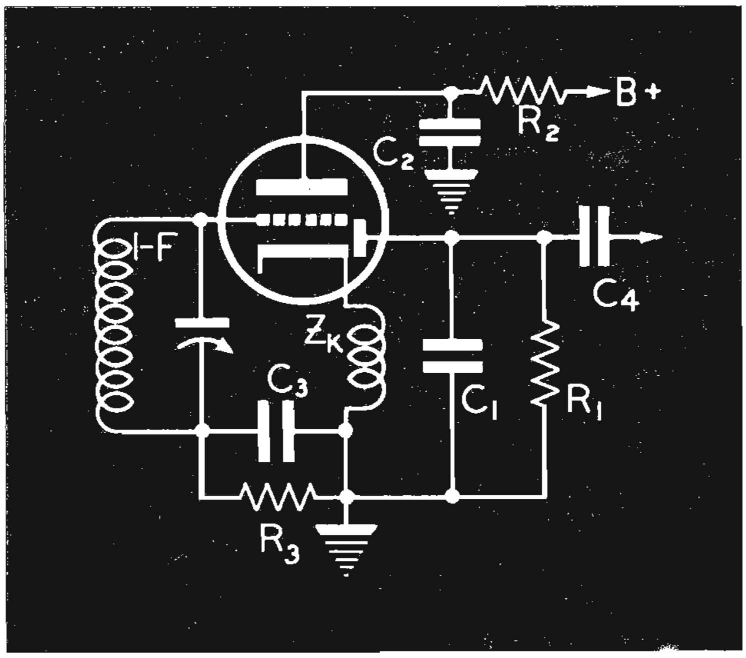
From the standpoint of distortion, the circuit has advantageous features. The triode can handle considerable power. This is further enhanced by its degeneration. Thus regulation is

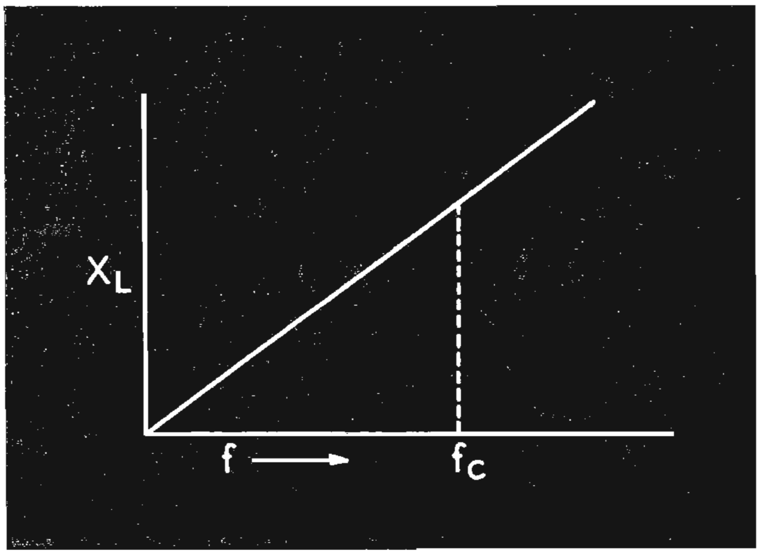
Figures 1 (top, left), 2 (top, right), 3 (center, right), 4-4a (center and below) A diode-triode detector circuit appears in Figure 1. In Figure 2 appears detector circuit of Figure 1 redrawn to show how diode is energized. Figure 3 shows a-c circuit of the triode portion of the tube, the cathode voltage being applied to the diode. In Figure 4 equivalents from Figure 3 are substituted. Figure 4 (a) shows a plot for gain versus cathode load for cathode coupled amplifier.






**Figures 5 (left) and 6 (top)**

**Figure 5 shows a frequency modulated detector. Figure 6, an idealized reactance curve of cathode inductance. Variations in frequency can be seen to cause reactance variations and thus variations in the voltage across the coil.**

very good. Distortion is accordingly prevented as the diode swings far positive with large percentages of modulation. Further, some non-linearity caused by curvature of the diode near cut-off is reduced because the input conductance to the diode is low. Thus the negative and positive peaks are less subject to distortion with high percentages of modulation.

With very slight modification, consisting only of changing the applied d-c electrode voltages, the circuit can also become useful as a frequency modulated detector, removing amplitude modulation (noise), changing the f-m to a-m and demodulating.

If the triode section of the detector has its plate and grid voltages reduced to a very low value, the plate current will saturate with low input voltages and any further increase in grid voltage will cause no further increase in a-c plate current. This is the action commonly desired in a limiter circuit and it can thus be seen that this action is similar. Amplitude variation are thus eliminated.

The assumptions made for the class *A* case no longer hold good. The values for $R_p$ and $\mu$ have no meaning and the value of $I_p$ as given in equation *4* no longer holds. Rather, $I_p$ becomes a constant as far as amplitude variations are concerned. Therefore the amplitude variations of a-c through the inductance in the cathode circuit do not exist. However, equation *3* still holds good and if the impedance in the cathode circuit is an inductance, its reactance is $2\pi fL$. The voltage developed across the inductance will be

$$E_k = I_p X_L \qquad (3)$$
$$= I_p 2\pi fL \qquad (6)$$

Thus any variations in frequency will cause corresponding changes in the voltage across the cathode inductance and since the diode circuit is connected across this cathode choke coil, the resulting voltage amplitude variations will be detected.

Let us now consider a frequency modulated wave applied to the grid of the tube. The amplitude variations will be eliminated by the constant amplitude of the plate current and the plate (or cathode) current may have the form

$$I_p = A \sin(\omega t + a \sin \alpha t) \qquad (7)$$

where $\omega = 2\pi$ times carrier frequency
$\alpha = 2\pi$ times mod. freq.

$$a = \frac{\omega}{\alpha} m$$

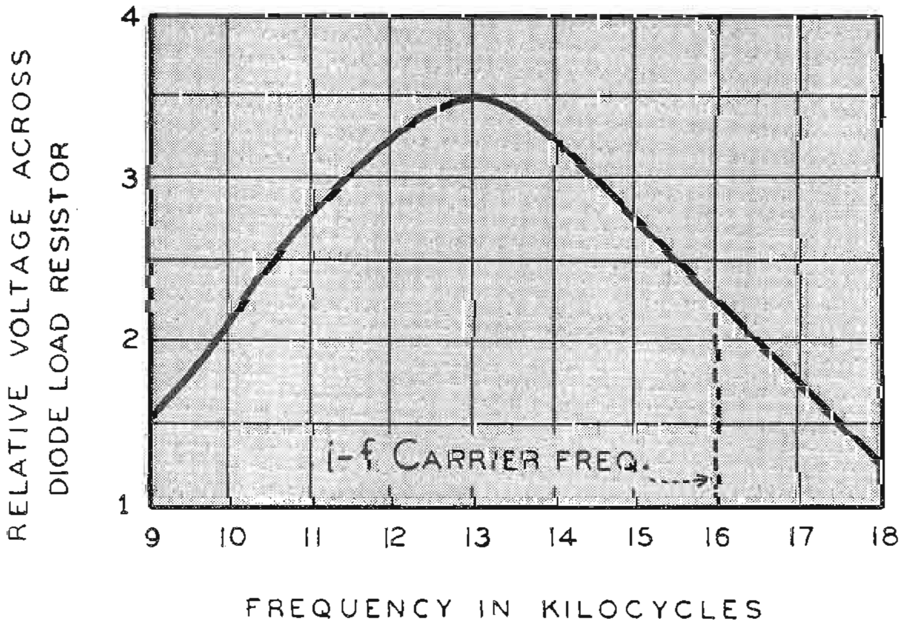
$$m \frac{\omega}{\pi} = mf = \text{freq. deviation.}$$

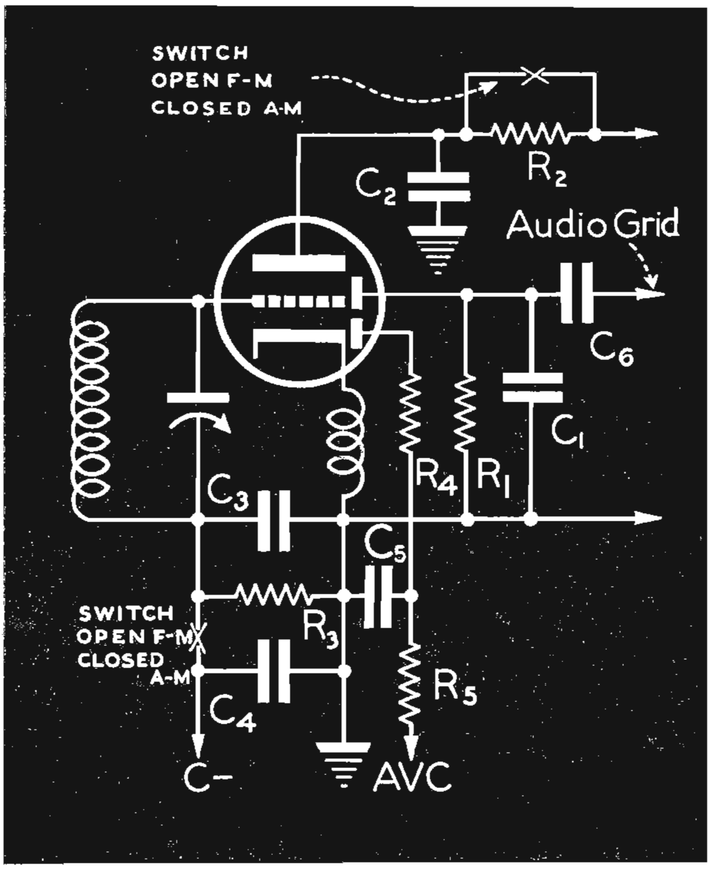
(*Continued on page* 94)

**Figures 7 (below) and 8 (right)**

**Figure 7, an approximate reactance curve of cathode inductance. Figure 8 represents the complete f-m/a-m detector.**

$R_1$, diode load resistor; $R_2$, plate voltage dropping resistor; $R_3$, ***grid-leak*** resistor for f-m bias; $R_4$, $R_5$, avc load and filter resistors; $C_1$, diode r-f bypass; $C_2$, plate bypass condenser; $C_3$, grid condenser for f-m; $C_4$, C-bias filter condenser; $C_5$, avc filter condenser; $C_6$, audio coupling condenser; $Z_k$, cathode impedance; $R_p$, plate resistance of triode. These identifying data cover components in all diagrams in this paper.



# A REPORT ON THE IRE

## Highlights of Papers Presented By Alexanderson, Lubcke, Smith, Wheeler, Whinnery and Jamieson, Edson McAllister, and Jett

**by LEWIS WINNER**

**Editor**

THE accelerated interest in radio was quite evident at the annual winter meeting of the IRE this year, at the Hotel Commodore in New York City. Over 1,700 engineers and executives were present. And they were well rewarded. For an unusual array of engineering and administrative papers were presented by members of the industry and government.

Among the many outstanding radio engineering personalities in attendance was the internationally famous Dr. E. F. W. Alexanderson of General Electric. The importance of this rare appearance was further amplified by his personal presentation of a paper on the amplidyne system.

The paper, entitled "The Amplidyne System of Control," prepared by Dr. Alexanderson in collaboration with M. A. Edwards and K. K. Bowman, analyzed the amplidyne from an application approach.

The amplidyne, said Dr. Alexanderson, is actually an amplifier used for power control. It is, he pointed out, a two-stage amplifier incorporated in one dynamo electric generator. The first stage, he said, is from the control field to the short circuit axis, while the second is from the short circuit axis to the load axis. Thus, he said, when we apply a voltage to the control field, there is a time delay before the corresponding current appears in a control field. A second time delay before the voltage appears on the output terminals thus results, he explained. This second time delay, he said, is caused by the inductance in the winding which prompts the short circuit current to lag behind the induced electromotive force.

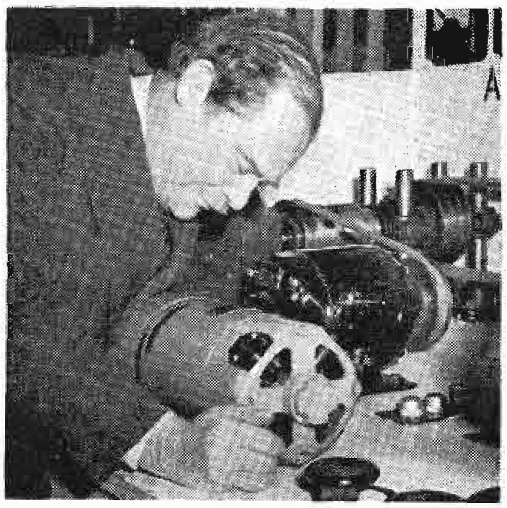
In his analysis of voltage amplification, Dr. Alexanderson discussed the machine used in making tests. It had a rotation frequency of 30 cycles; a rating of 8 amperes at 250 volts. Dr. Alexanderson pointed out that from these data it is possible to predict the amplification available at any frequency. Amplification must, of course, be resolved into voltage and current amplification, he said. However, said Dr. Alexanderson, the voltage amplification factor is the most important of the two. He said that this amplification can be expressed by the simple formula

$$\mu = \left(\frac{f_o}{f}\right)^2$$

where $f_o$ is the rotation frequency, and f the control frequency.

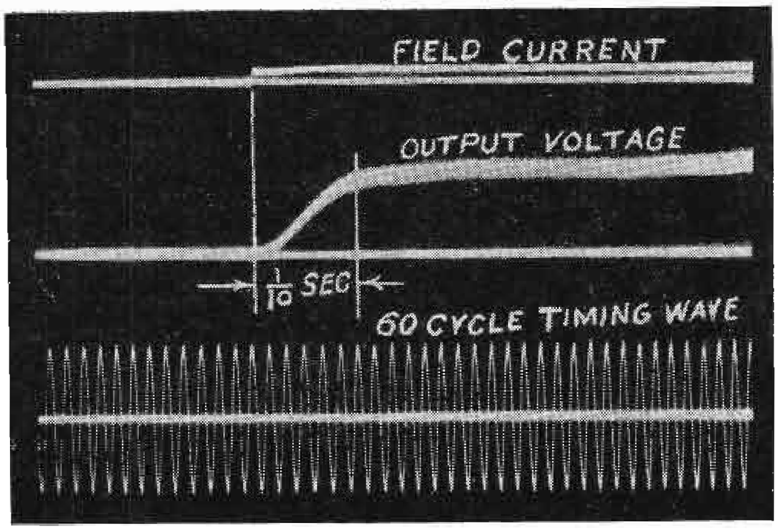
Dr. Alexanderson also analyzed anti-hunting systems. Such systems, he said, may reduce amplification, which is usually permissible. We may effect a compromise, he explained, whereby the amplification is reduced for frequencies around 2 cycles and the steady-state amplification remains at full value.

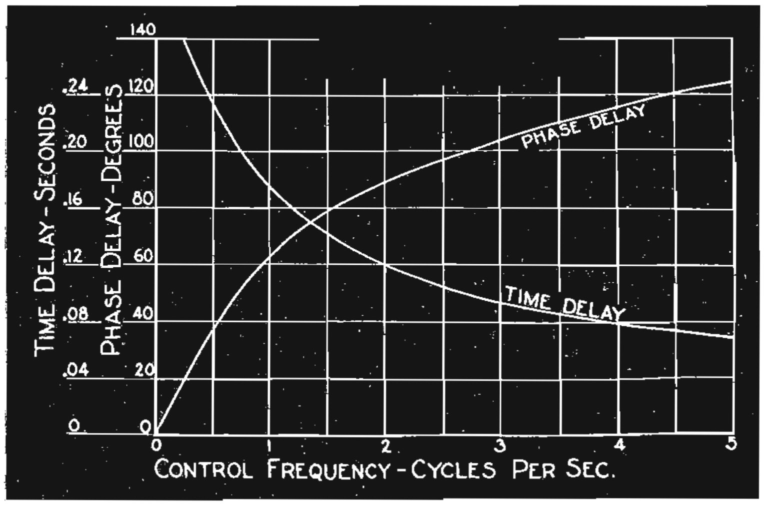
In a discussion of the practical limits of accuracy, Dr. Alexanderson said that the limit of stiffness of the control

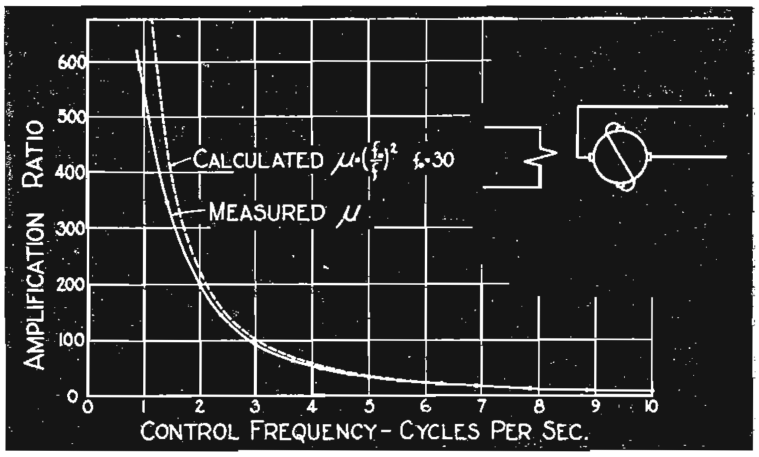


Figures 1 (left) and 2 (right).

Figure 1, Dr. E. F. W. Alexanderson and the amplidyne which he discussed at the IRE meeting. Figure 2 illustrates the characteristic time-delay properties of the amplidyne.






Figures 3 (left) and 4 (above)

In Figure 3 appears a plot of the time-delay characteristics of the amplidyne. Figure 4 discloses amplidyne voltage amplification characteristics.

circuit is reached when a corresponding natural period is a frequency where the capacity impedance of the motor circuit is equal to the inductive impedance.

### Orthicon Cameras

A PAPER on "Orthicon Cameras in Television Studio Work" was presented by H. R. Lubcke, director of television of the Don Lee broadcasting system, Hollywood, California.

Mr. Lubcke pointed out that the orthicon pickup tube has proved very satisfactory, affording in some instances improved results over the iconoscope. He said, for instance, that the excellent light sensitivity of cameras utilizing the orthicon allows a reduction of incident light on the stage to 250-foot candles from the previous value of 1,000-foot candles for the iconoscope. With a fifty per cent reflection factor as from the face, he said, a brightness of 130 footlamberts is sufficient. This, he explained, corresponds to a Weston reading of 15. And at the same time, he stated, a greater depth of focus is realized. This results, he said, from an allowable decrease in lens aperture from f2.7 to f6.3 or better.

It is necessary to adjust the orthicon camera carefully before the program, pointed out Mr. Lubcke. Readjustments during the program should be of limited scope, he said.

He showed that the elimination of shading error allows striking presentation of lightly costumed actors against velvet backdrops. Images thus appear with greater realism providing a *roundness* to objects rather than the *flat* picture that often characterizes iconoscope pickup. In discussing lighting and makeup technique, he said that the orthicon did not require any different technique than the usual television and motion picture procedure.

### The Quantum Theory

A DISCUSSION of "The Limitations Imposed By Quantum Theory on Resonator Control of Electrons" was presented by Lloyd P. Smith of Cornell University, who is now temporarily with RCA as a consultant.

Dr. Smith pointed out that when an electron interacts with a high frequency electromagnetic field, it does not exchange energy with this field in a continuous manner. The quantum theory, he said, requires that the energy change must occur in discrete energy steps of one quantum each where the energy quantum is $h\nu$. When the frequency is not high, he said, these energy steps become very small indeed (for $\nu = 10^6$ cycles per second, $h\nu = .004$ microvolts). But, he explained, the energy exchange takes place by a great number of small successive steps so that it would appear to take place continuously.

Where the frequency becomes large, he stated, this step-wise exchange of energy leads to results which differ from those one would expect from the classical electrodynamics. For, he

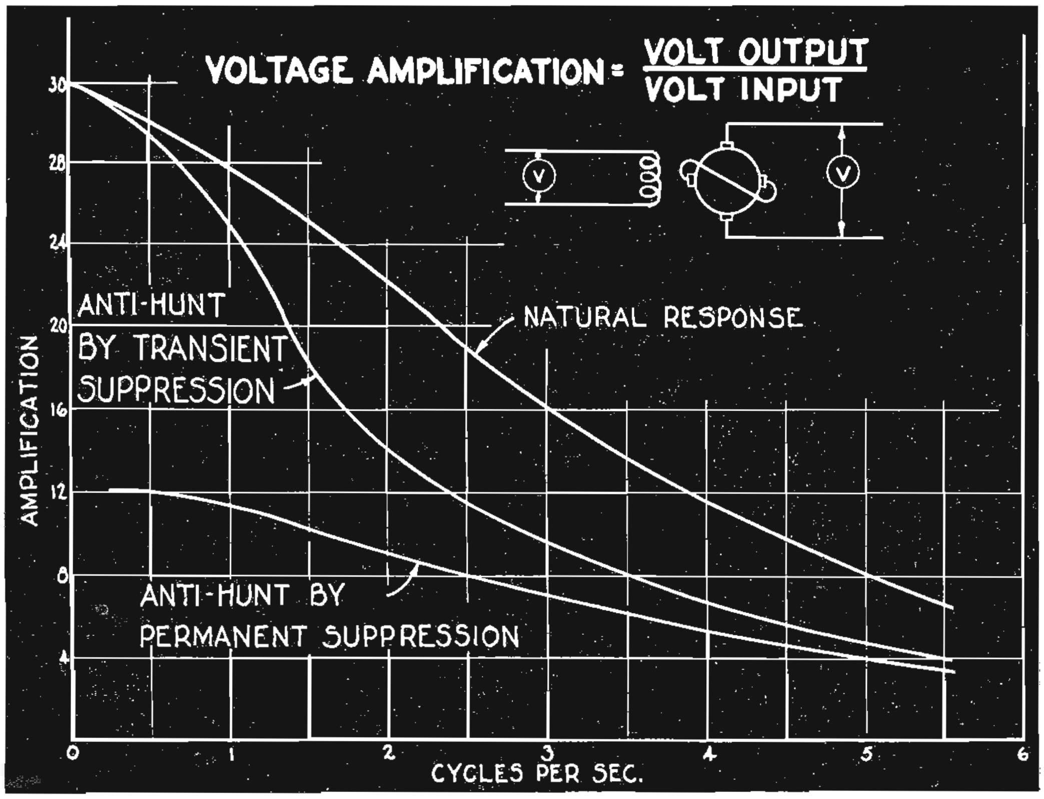



Figure 5

Resultant plot, when anti-hunt methods are used in an amplidyne.

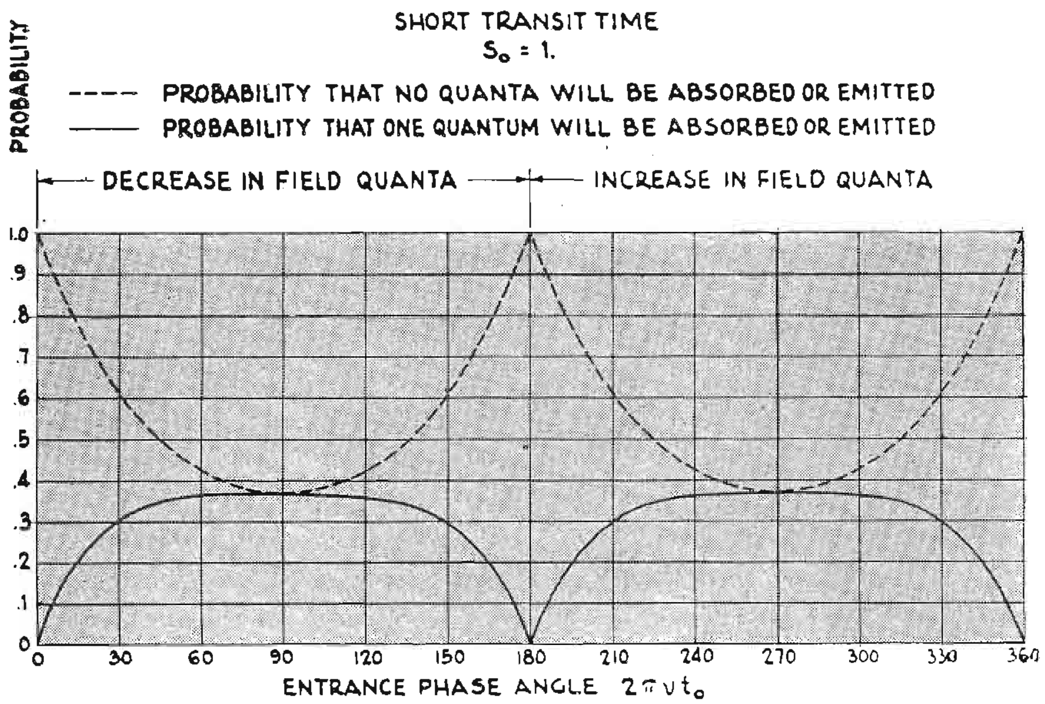



Figure 6

One of the quantum probabilities discussed by Lloyd P. Smith in his paper on the quantum theory. From this plot we note that the number of electrons that make a transit without gain or loss of energy is very appreciable at $S_0 = 0$.

said, at 30,000 megacycles the quantum is 123 microvolts. Thus, the electron volt energy of an electron would have to change in steps of this amount.

According to the quantum theory, we cannot know specifically whether under favorable condition an exchange of one quantum will take place in a given interval of time, explained Dr. Smith. We can only know, he said, the probability that the exchange will take place in a given time. This of course leads us to suppose that it will be possible for an electron to pass through an excited resonant cavity without having had its energy changed, he said, even though from classical considerations it would certainly have experienced an energy change. This phenomena, he explained, leads to a certain lack of control of the energy of a beam of electrons at high frequencies and low resonator field strengths.

He pointed out that when the classically computed maximum energy change that the electron can experience becomes comparable with a quantum energy at a given frequency, about one-half of the beam current would be unaffected by the field in the cavity. The implication of this with regard to the control of electron beams in h-f velocity modulation tubes is of considerable importance, he concluded.

### The Piston Attenuator

THE development, design and application of the "Piston Attenuator" were covered in an interesting presentation by Harold A. Wheeler of Hazeltine Electronics Corporation.

The piston attenuator, said Mr. Wheeler, was the forerunner of the waveguide, bearing the same relation to the waveguide as a ladder attenuator bears to a highpass filter. In the attenuation band, the electric and magnetic fields act separately. In the pass band, however, he said, both fields are interlocked in an electromagnetic wave.

Fifteen years of study and use have gone into the development of the piston attenuator. In 1932, said Mr. Wheeler, we built the first complete signal generator using the coaxial piston inductor. In that design, he said, the coplanar type of coupling discovery was made. And in 1935 it was used in a complete signal generator.

Mr. Wheeler's discussion covered the piston capacitor, coaxial piston inductor, and the coplanar piston inductor. He pointed out that the coplanar piston inductor is the best type because it is more reliable for large attenuation. A 32 db change in the attenuation occurs in a circular cylinder when the piston is moved by a distance equal to the inside diameter, explained Mr. Wheeler. At high frequencies, he said, the movable pickup coil becomes a small loop connected with a flexible cable. And instead of providing a primary coil, that end of the cylinder may be mounted on the side of a line or cavity resonator, he explained, so that the cylinder receives its magnetic field directly from the cavity. A rack and pinion is ordinarily used to drive the piston, explained Mr. Wheeler, and a dial calibrated directly in db is used.

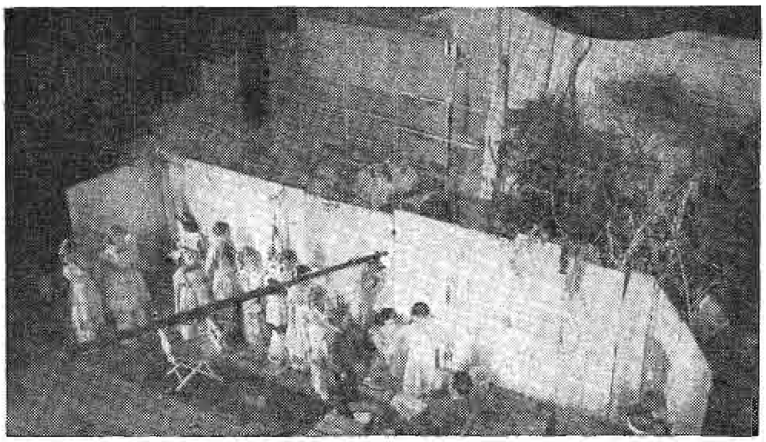
The advantages of the piston attenuator, according to Mr. Wheeler, are many. For instance, he said, it is a primary standard of attenuation, since it is determined by the dimensions of the shield. In view of this, he said, the attenuation scale can be computed in advance and need not be calibrated by tests. In addition, he added, the attenuator is mechanically and electrically rugged.

### Transmission Lines

DISCONTINUITIES in transmission lines were analyzed in a paper by J. R. Whinnery and H. W. Jamieson of General Electric.

Abrupt changes in outer diameter or inner diameter or both diameters of a coaxial line, or the change in height of a radial transmission line demand careful study. Such discontinuities are common in power transmission and measurement applications at ordinary radio frequencies. However, pointed out Mr. Whinnery who presented this paper, entitled "Equivalent Circuits for

Figures 7 (left, below) and 8 (right, below) In Figure 7, a typical television set using the orthicon cameras described by Harry C. Lubcke of the Don Lee System. This set is 100' x 60' x 30' high. In Figure 8, four scenes being prepared at Don Lee studios for telecasting.



Discontinuity in Transmission Lines," these discontinuities are quite common in the use of transmission lines as elements in resonant cavity type circuits in the microwave region. The quantitative effects of the local fields about the discontinuity at these highest frequencies, said Mr. Whinnery, are available by measuring. A class of discontinuities exist, however, for which the equivalent circuit can be predicted from theoretical considerations, explained Mr. Whinnery. Values calculated for elements appearing in such circuits were considered in this paper.

Discontinuities in the simple ideal parallel plane transmission lines were discussed, with the identical equivalent circuits being applied to the corresponding coaxial line discontinuities.

If transverse dimensions between conductors are small compared with wavelength, pointed out Mr. Whinnery, the discontinuity admittance is a pure capacitance and a function only of the geometrical configuration. If the discontinuities are symmetrical about a plane midway between conductors, the values of discontinuity capacitance are just half those for the corresponding unsymmetrical problem, he explained.

Explaining "reentrant" type discontinuities at the bottom, Mr. Whinnery pointed out that their equivalent circuit consists of three transmission lines connected in series, the *a, b* and *c* lines, with a lumped capacitance shunted across each line at the junction.

A series of curves made on coaxial line discontinuities were presented together with experimental measurements for verification. In one such setup a resonator consisting of two coaxial line sections with a discontinuity of a third type was used, and according to Mr. Whinnery, the measured value of resonant frequency checked the calculated value including the discontinuity capacitance within 1%, although this frequency was about 23% different from that calculated, neglecting the discontinuity capacitance. For the second setup, a composite line was constructed. Measurements were made in the centimeter wave region, explained Mr. Whinnery, thus serving not only as experimental checks but as a means of studying the effects of such discontinuities at high frequencies.

**Oscillators**

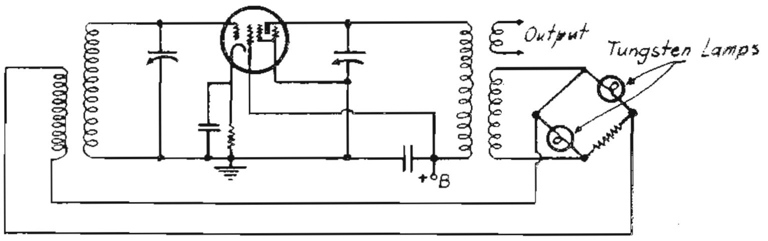
An extremely thorough study of oscillators was presented by W. A. Edson, Bell Telephone Laboratories, Inc., in his paper on "Intermittent Behavior in Oscillators."

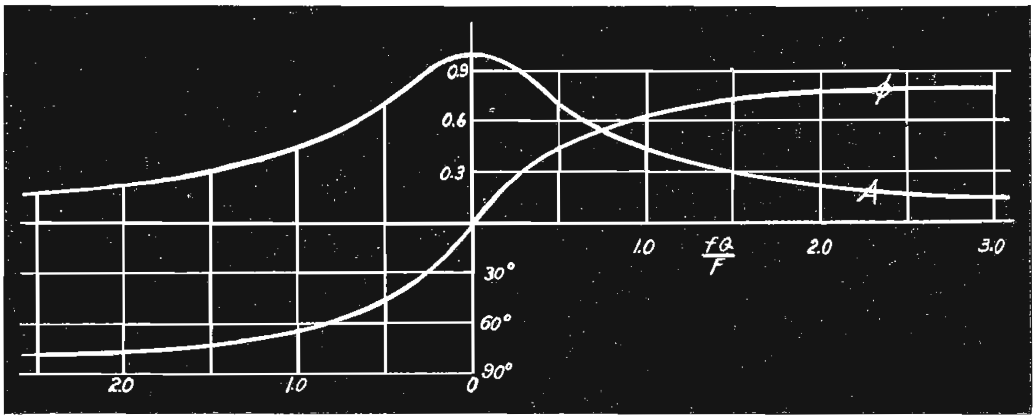
Discussing oscillators basically, he

(*Continued on page* 100)

Figures 9 (right) and 10 (below)

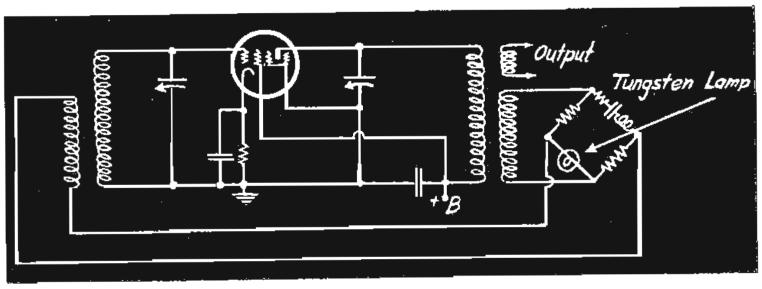
In Figure 9, schematic diagram of lamp-stabilized oscillator discussed by W. A. Edson in his paper on "Oscillators". Figure 10, characteristics of a single-tuned circuit.

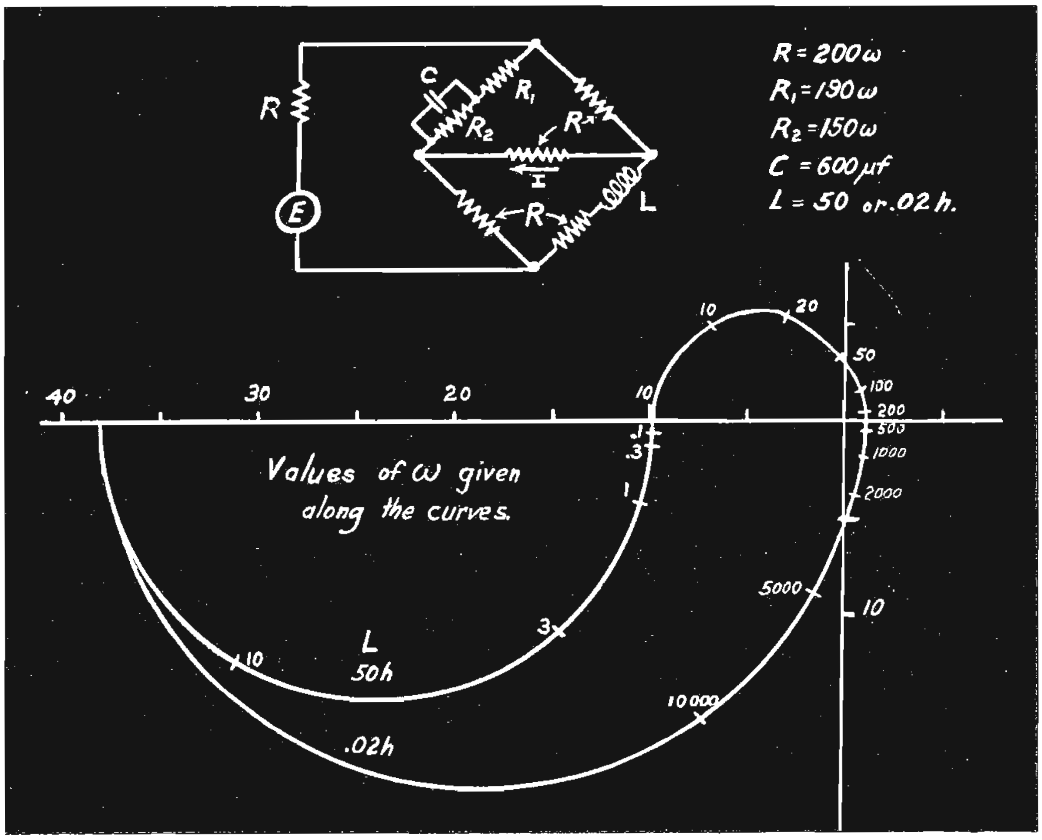



Figures 11 (right) and 12 (below)

Figure 11, the Meacham circuit discussed by Mr. Edson. Figure 12, characteristic behavior of a Meacham bridge.



# SIGNS OF VOLTAGES AND CURRENTS

## In Vacuum Tube Circuits

by H. STOCKMAN

Instructor of Physics and Communication Engineering, Cruft Laboratory, Harvard Universty

IN the study of vacuum tube theory, signs of voltages and currents, or, to be more precise, the lack of signs of voltages and currents appear to puzzle many.

A correct determination of phase angles can only be made if the quantities the angle refers to are clearly defined. It is, for example, right to say that at mid-frequencies the phase shift of a resistance-coupled single stage amplifier is approximately 180°, but it may be equally correct to say that the same amplifier has a phase-shift of approximately 0°. Since today, phase angles are of almost the same importance as amplitudes, the correct determination of phase angles, or the correct determination of signs of voltages and currents, is an item of major importance.

Discussion of signs generally poses questions concerning fundamental tube-theory, and in a case like this it is as well to accept the procedure of studying signs as they appear in a brief review of vacuum tube fundamentals.

The question of proper signs is a serious one, causing difficulties not only for students but for experienced engineers. The present sign-convention, or rather sign-conventions, are not ideal, and cause disagreement and unnecessary confusion. This fact is to some extent illustrated by two references in the text, one taken from the American and the other from the European literature. Many suggestions to improve conditions have been given in the past, often with the aim of eliminating obstacles in the way of the student; obstacles which were accidentally introduced in the early days of developments. This paper does not propose a particular sign-convention for adoption, but merely points out the fact that if we understand the signs, *and the necessity for signs*, it is not important which convention we adopt, as long as we adhere strictly to it. The conventions adopted should be those which lead to the greatest economy of mental effort in following the various processes represented by the chosen symbols.

### The Tube Coefficients

Let us consider the simple tube circuit shown in Figure 1 (a) and (b), for d-c and a-c conditions. Tube capacitances are, for simplicity, neglected and freedom from grid current assumed. The directions of the d-c quantities in Figure 1(a) are indicated by means of plus-minus signs and all differentials counted in the directions of the steady components.[1] The tube coefficients are here treated as numerical values (as in the practical field, excepting ultrahigh frequencies) and they are defined under *static* conditions, i. e. with the electrodes free from loading impedances. Thus when the circuit in Figure 1(b) is used for determination of tube coefficients, it may be considered open at the dotted line, in which case $E_p$ is an applied electrode voltage.

In many uses tubes with a single control-grid may be considered to respond linearly to variations in the steady components $e_c$, $i_b$, $e_b$. This means that with all grids except one at fixed potentials, the grid serving as control grid contributes a plate current variation $a\Delta e_c$ and the plate, a plate current variation $b\Delta e_b$, *a* and *b* being constants. By law of superposition the total plate current variation is then

$$\Delta i_b = a \Delta e_c + b \Delta e_b \qquad (1)$$

Determining the coefficients *a* and *b* as limits for $\Delta$ – ratios, *a* may be defined for $\Delta e_b = 0$ as

$$a = g_m = \left.\frac{di_b}{de_c}\right|_{e_b} = \text{transductance} \qquad (2)$$

Similarly, for $\Delta e_c = 0$,

$$b = g_p = \left.\frac{d\,i_b}{d\,e_b}\right|_{e_c} = \text{plate conductance} \qquad (3)$$

where

$$1/g_p = r_p = \text{plate resistance} \qquad (4)$$

Further, for $i_b$ = constant,

$$a/b = \mu = -\left.\frac{de_b}{de_c}\right|_{i_b} = \text{amplification factor} \qquad (5)$$

Thus

$$\mu = g_m/g_p = r_p\, g_m \qquad (6)$$

Within the region of linearity the tube characteristics will be straight, parallel, equidistant lines. A space model of tube characteristics will show a flat surface within the same region.

### Equivalent Plate Circuit Equation

Definitions *2, 3,* and *5* and equations involving them must be read with the circuit of Figure 1(a) as a background. Without voltage and current directions the defined quantities are of limited use for calculation.

It is of the greatest importance to realize that equation *1* is not obtained as a result of a derivation, but is an assumption or agreement of value for certain tubes in certain uses (distortion-free amplifiers). Actually, the numerical values of the coefficients *a* and *b*, or $g_m$ and $g_p$, are in almost all cases obtained from practical measurements. Equation *1* is therefore the very beginning of the tube-circuit theory, dealing with the tube as a linear, passive, bilateral[2] circuit element. Equation *1* is as well the end of this theory. Written for variations of sinusoidal form and in conventional notation[3] it has the form

$$i_p = g_m\, e_g + g_p\, e_p \qquad (7)$$

or

$$|I_{pm}| \cos(A\,t + \gamma) = g_m\,|E_{gm}| \cos(A\,t + \alpha) + g_p\,|E_{pm}| \cos(A\,t + \beta) \qquad (8)$$

These three sinusoids have arbitrary phase relations indicated by the phase-angles $\gamma$, $\alpha$ and $\beta$, measured from a common reference. If the cosines in equation *8* represent projections from the three phasors[4] $I_{pm}$, $E_{gm}$, and $E_{pm}$ on the real axis of an axis system in a complex plane, equation *8* may be more

[1]Notations without plus-minus signs (or single-headed arrows) should be avoided. For rules concerning signs in network calculations see *The Potentiometer Idea in Network Calculation*, IRE Proceedings, pp. 85; February, 1943.

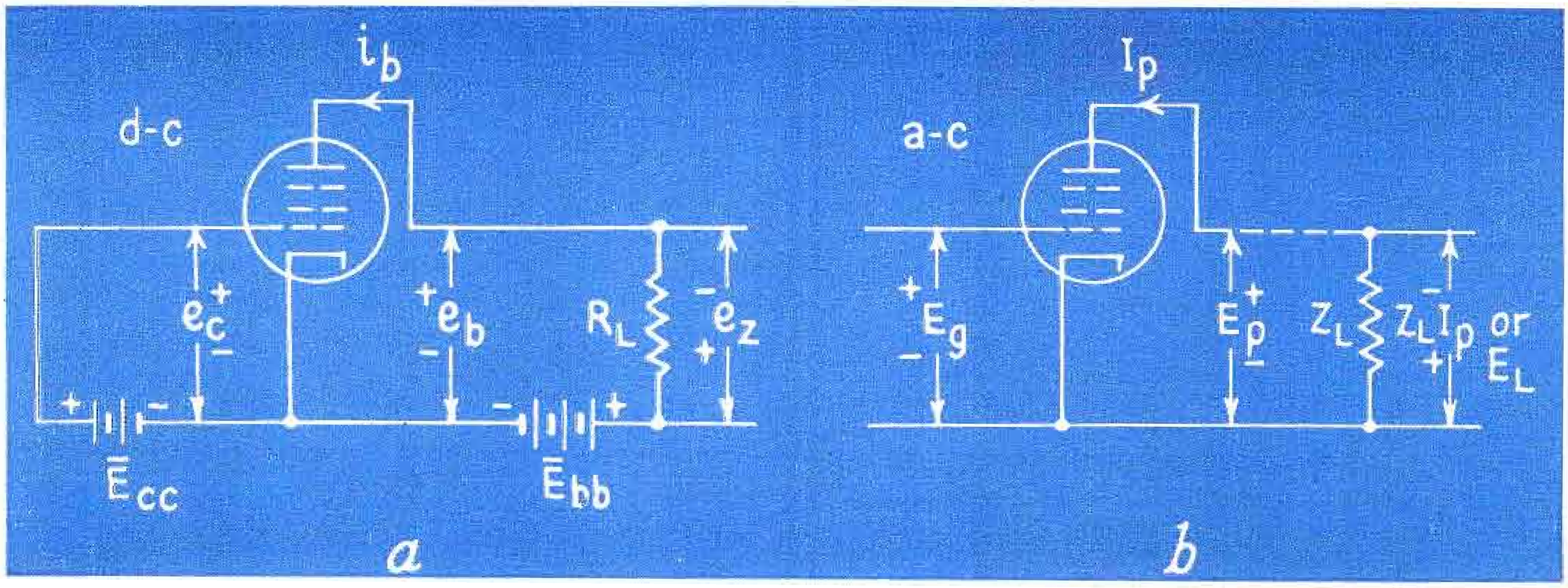



Figure 1
Vacuum tube circuit under d-c and a-c conditions with the directions of currents and voltages indicated.

conveniently written with complex rms variables as

$$I_p = g_m E_g + g_p E_p \qquad (9)$$

With $Z_L I_p = - E_p$ from Figure 1(b) and $r_p g_m = \mu$ from equation *6*,

$$I_p = \mu E_g/(r_p + Z_L) \qquad (10)$$

These equations are probably the most important ones that can be written down for the tube as a linear circuit element. Equation *9* may be with advantage referred to as *the tube equation*. Written as equation *10* the tube equation is widely known as the *equivalent plate circuit theorem*, and will here be called *the EPC equation*. The ohm's law in equation *8* yields the circuit diagram shown in Figure 2(a), which circuit is equivalent to the plate circuit of the tube. The series circuit in Figure 2(a) with the constant-voltage generator "$\mu E_g$" may by means of Norton's theorem be transformed to the parallel circuit of Figure 2(b) with the constant-current generator "$g_m E_g$." This transformation could as well be obtained by direct inspection of equation *9*, which reveals that the current $g_m E_g$ has two branch components, $I_p$ (through the load $Z_L$) and $-g_p E_p$ (through $r_p$, thus shunting $Z_L$). Another way of obtaining the transformation is to multiply equation *10* by $Z_L$ and substitute $r_p g_m$ for $\mu$. Thus we obtain

$$Z_L I_p = E_L = - E_p$$
$$= r_p Z_L/(r_p + Z_L) \times g_m E_g \qquad (11)$$

At this point it may be well to stop and consider the signs. Although the signs of the d-c quantities in Figure 1 are optional, they were chosen to satisfy the actual directions in the physical circuit. Further, although the directions of the differentials are optional, they were chosen in the same directions as the steady-state quantities. Finally, although the directions of the a-c quantities are optional, they were chosen to agree with the signs of the differentials. But the fact that any quantity may be given any direction (if the equations are written accordingly) is stressed by the introduction of double notations for the plate voltage, $E_p$ and $E_L = -E_p$. The voltage amplification, V = A, in a resistance-coupled amplifier may at mid-frequencies be obtained from the equivalent circuit in Figure 2 to

$$V = A = -\mu Z_L/(r_p + Z_L) \qquad (12)$$

and may equally well be written

$$V = A = \mu Z_L/(r_p + Z_L) \qquad (13)$$

V = A is used above in two different meanings (the notation V = A is sometimes inconvenient), as it represents $E_p/E_g$ as well as $E_L/E_g$. If one V = A notation is mistaken for the other, an error of 180° results.

### Single-Control-Grid Circuits

Let us consider the amplifier circuit in Figure 3. It is of interest to calculate the overall voltage-amplification to amplitude and phase, i. e. the complex ratio $E_{L3}/E_{g1}$. If, here, the voltages referred to were introduced without any sense of direction, a single-valued expression for the phase-shift in the amplifier could not be obtained. It is true that an experienced engineer may work out the phase angle correctly without the aid of plus-minus signs (or single-headed arrows), but that is only because he keeps a sense of direction somewhere back in his head. Unfortunately his own secret convention does not always check with the convention of the student, to whom he explains how to calculate phase angles. The writer admits that under certain conditions it may be sufficient to state that the variational voltages are counted positive with respect to the chassis, but new agreements are then necessary whenever voltages are encountered between *hot* points free from the chassis. Information that the voltages are *measured with respect to the chassis*, or with respect to some other given point, tells where one lead of the checking voltmeter goes, but *does not convey any reliable information regarding the direction of the*

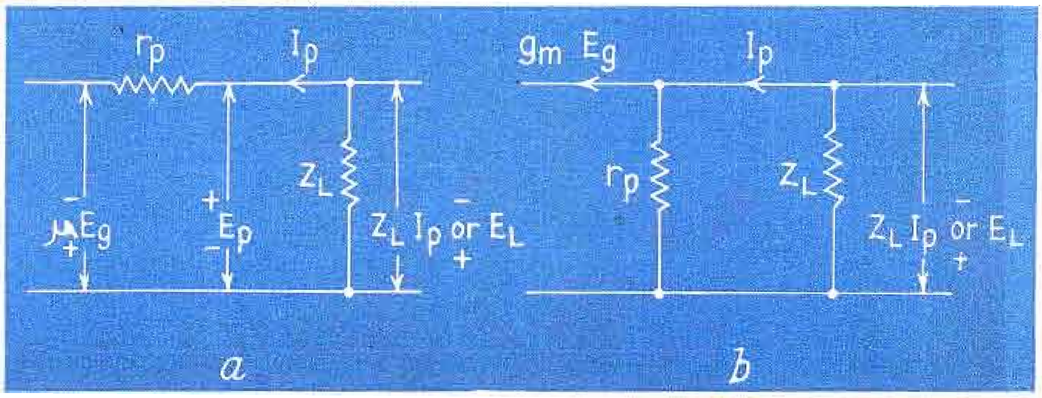



Figure 2
Series and parallel form of the equivalent plate circuit of the tube in Figure 1.

[2]Bilateral means here independent of current direction. A tube may only be bilateral under restricted conditions (variations much less than the steady values).

[3]Appendix *3*, end of paper.

[4]The term *phasor* is used by AIEE and is here preferred for *vector*, which in the antenna and wave-propagation field, is used extensively in the meaning space vector. The writer prefers, however, the translation of the European term for a fictitious rotating complex quantity, namely *pointer*.

*voltages.* There is only one safe way out of the difficulty and that is to indicate the direction of every concerned voltage and current in the circuit diagram. It is better to overdo than to underdo the sign business, even if one runs the risk of being considered *sign-conscious.*

In agreement with the above discussion the voltages introduced in the amplifier circuit are given plus-minus signs. The directions are optional, even if it sometimes is practical to do as some engineers do. They put the signs as closely as possible the way they appear in reality. In Figure 1 we had an example on the use of two different notations for one and the same thing, $E_p$ and $-E_L$. If a tube has many electrodes, it is as well to count all voltages positive upwards. In output calculations, however, it is often practical to use $E_L$ for $Z_L I_p$, without the introduction of a minus sign. As there is a clear and sharp definition, $E_p = - E_L$, no ambiguity whatsoever is involved in the use of two notations. In Figure 3 a similar situation appears with $-E'_{L1}$ and $E_{g2}$, respectively $-E'_{L2}$ and $E_{g3}$. Thus each amplifier stage appears with plus on the grid, which may be an advantage if a standard formula for calculation of amplification is adopted. If *n* is introduced as the complex ratio $E_L/E'_L$ (the last stage has $n_3 = 1$), the total amplification of the amplifier can easily be written down directly as

$$E_{L3} = 1/n_3 \times Z_{L3}/(r_{p3} + Z_{L3}) \times \mu_3 \times E_{g3}$$
$$(- 1/n_2 \times Z_{L2}/(r_{p2} + Z_{L2} \times \mu_2 \times E_{g2}$$
$$(- 1/n_1 \times Z_{L1}/(r_{p1} + Z_{L1}) \times \mu_1 \times E_{g1}.$$

$$E_{L3}/E_{g1} = \frac{\mu_1 \mu_2 \mu_3 \ldots Z_{L1} Z_{L2} Z_{L3} \ldots}{n_1 (r_{p1} + Z_{L1}) n_2 (r_{p2} + Z_{L2}) n_3 (r_{p3} + Z_{L3})} \quad (14)$$

In this way the commonly experienced error of a 180° phase shift in answers may be avoided.

It is of interest to note that the amplification in the amplifiers of Figures 1(b) and 3 is calculated, treating each stage as a potentiometer circuit, currents being avoided entirely in the computation. There are other networks where quicker and safer calculation is made possible by avoiding voltages and dealing with currents entirely. To know when to dodge currents and when to dodge voltages is a question of experience.

It seems now that all the above formulae just fall out of the mathematics and that no further discussion is needed. It must be realized, however, that the signs obtained are only logical results of the sign assumptions made. By locating currents and voltages differently as far as signs are concerned, we could obtain different definitions and should then have to write our equations accordingly.

An interesting example of what may come out of assumptions different from the ones made in Figure 1 is obtainable from a suggestion made by H. A. Wheeler[5] some time ago. Wheeler points out that it is conventional to look upon a generator as a source, which delivers a current going out from the output electrode. And if the direct plate current is directed out from the tube through the plate, the plate current is negative. Therefore an increase in the direct plate current is a negative change. It is accompanied by a negative change in the direct plate voltage. From the point of view of filter theory the tube now behaves as a straightforward transducer, the changes in current and voltage going in the same direction.

[5]*Transconductance*, IRE Proceedings, pp. 385, vol. 28, II; August, 1940.

The point brought out by Wheeler regarding the transducer action is illustrated here by the comparison made in Figure 4 (a) and (b). The transfer admittance $Y_m$ is, in both cases, expressed by the ratio between the output current and the input voltage. If, for simplicity, the network is assumed to be resistive and $Z_L = 0$, then for the network,

$$Y_m = \frac{I_2}{E_1}$$

and for the tube

$$Y_m = \left.\frac{di_2}{de_1}\right|_{e_2} = -g_m \quad (15)$$

The tube is therefore treated in the same way as a network or filter, the consequence being that the definition of transconductance now involves a minus sign. (Namely, if the notation $g_m$ is considered still to check with the physical phenomena in the tube, so that it indicates, for example, how many microamperes enter the tube through the plate, when the grid is made one microvolt positive). Further amplification factor as well as plate resistance will be defined with minus signs.

The main objection to Wheeler's suggestion to direct alternating plate current as leaving the tube through the plate, has been given as the great difficulties involved in a change in already accepted engineering practice. The network engineer, who is used to clockwise currents, should no doubt appreciate the adoption, but the tube engineer would probably not. The tube engineer is generally concerned with single-mesh and two-mesh loads only, such as tank circuits and double-tuned transformers, and to him the convention of one anti-clockwise and one clockwise current is fully agreeable. His derivations of input impedance, transfer impedance, iterative impedance, etc., will be correct, although not of conventional form when compared with derivations in textbooks on networks and filters. The question of current directions involves as well, the question of how to define positive mutual inductance + M. Since this matter is too extensive to be brought up in this connection, we will leave it with

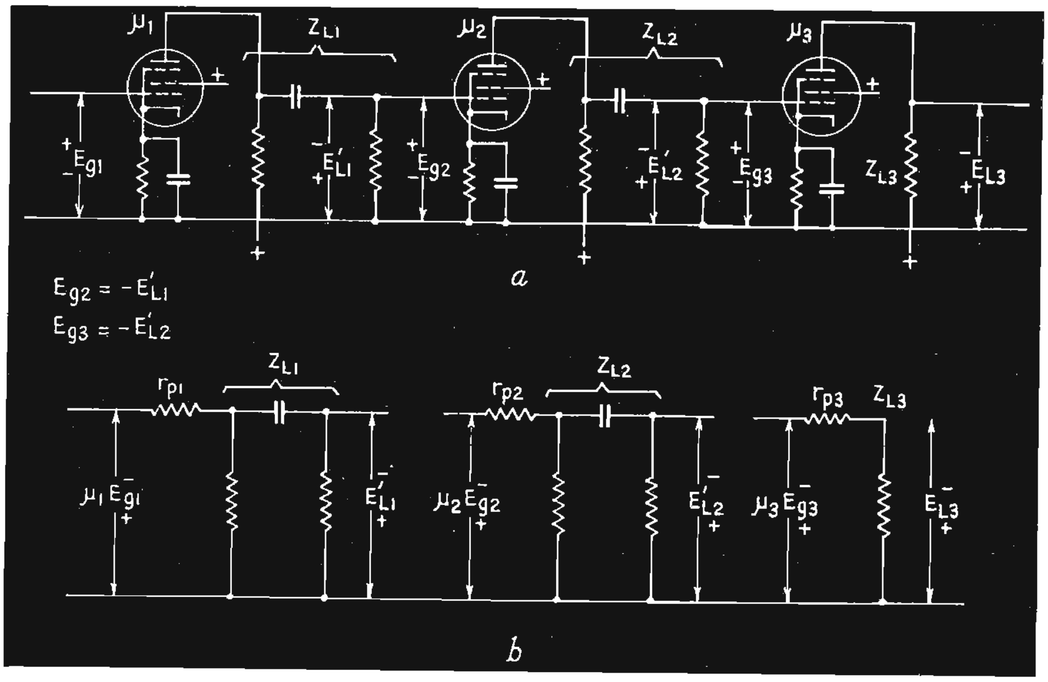



**Figure 3**

**Amplifier circuit and its equivalent, illustrating extensive use of signs in phase-angle calculations.**

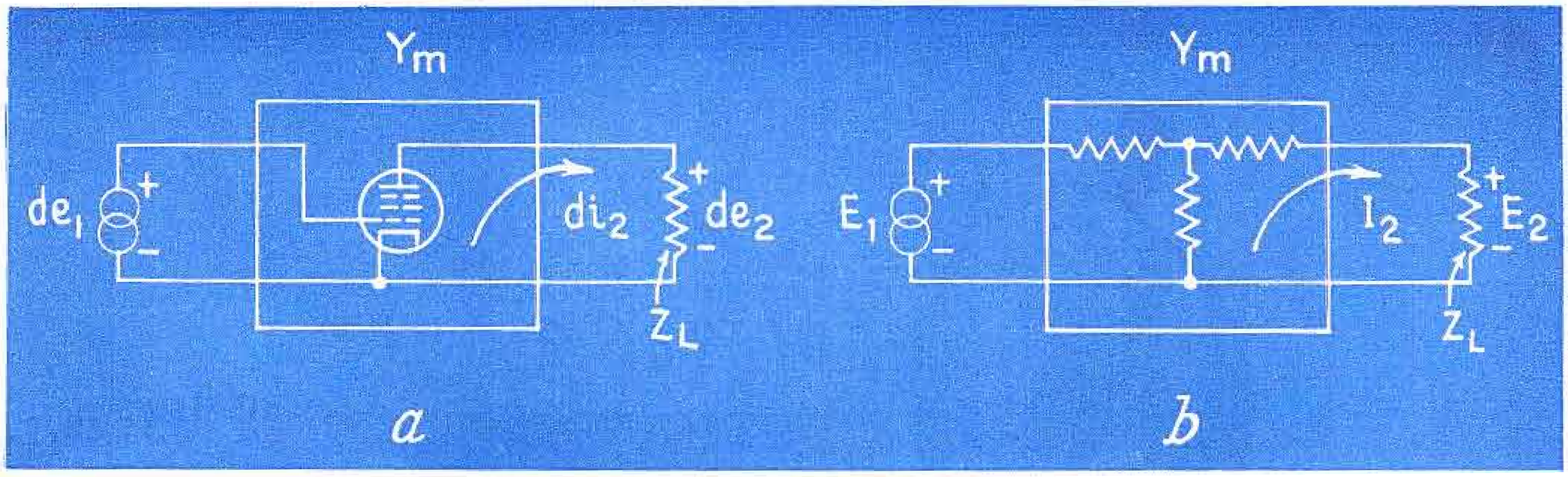



Figure 4

Comparison of tube transducer and network transducer with respect to signs.

the statement that the definition of +M is frequently tied together with the direction of the two loop-currents.

Further evidence of disagreement regarding signs of voltages and currents in tube circuits is given in an interesting discussion by Professor G. W. O. Howe, technical editor of Wireless Engineer (Appendix 1). The reader of this extract will probably realize that each one of the three authorities involved is treating his subject correctly. At the same time one cannot avoid feeling that further standardization in the interest of generally adopted sign-rules would be very much welcomed. (Note that the criticism given by Professor Howe applies at least in part to this paper as well, as the author has largely adopted the terminology of one of the two authorities mentioned.)

### Double-Control-Grid Circuits

Consider temporarily a tube with one control grid only. The $i_p e_c$ – characteristic for this tube is shown in Figure 5. For $Z_L = 0$ the operation of the circuit is described by equation *9* with the second term equal to zero. The path of operation then coincides with the *static* characteristic $g_m$ in Figure 5. If now $Z_L$ is given a certain value, a second term will appear in equation *9*, so that with $E_p = -Z_L I_p$,

$$I_p = g_m E_g - g_p Z_L I_p \qquad (16)$$

The contribution from the plate appears with opposite sign to the contribution from the control grid, and whatever sign we give the first term, the second term will always appear with the opposite one (excepting conditions at ultrahigh frequencies from the discussion). The ratio between plate-current variation and control-grid-voltage variation still is of interest and will now be referred to as the *dynamic* transadmittance $Y_m$, which by equation *16* is given to

$$Y_m = g_m/(1+Z_L/r_p) = Kg_m, \qquad (17)$$

where *K*, as well as $Y_m$, are complex quantities. Equation *17* represents an ellipse. For resistive load $Z_L = R_L$ the quantity *K* becomes real and the ratio $1/(1+R_L/r_p)$ now illustrates the reduction in slope due to the presence of the load in the plate circuit. The *reduction in slope* is the direct result of the *negative sign* in equation *16*

The plate current $I_p$ may be calculated either from the *dynamic* characteristic $Y_m$ or from the *static* characteristic $g_m$. In the first case equation *17* states that $I_p = Y_m E_g$, where $E_g$ is the applied grid voltage. In the second case the high slope $g_m$ is actually not the one producing the variational plate current, so using $g_m$ we must introduce a correction by substituting a reduced voltage $(E_g)_c$ for $E_g$. The fictitious voltage $(E_g)_c$ may be referred to as the *grid-control voltage*, and may be defined by the relation

$$I_p = Y_m E_g = g_m (E_g)_c$$
$$= g_m/(1+Z_L/r_p) \times E_g \qquad (18)$$

to

$$(E_g)_c = E_g + E_p/\mu \qquad (19)$$

Equation *19* is easiest realized from the fact that $\mu(E_g)_c$ is the voltage that drives the current $I_p$ through the plate resistance $r_p$, the drop being $r_p I_p = \mu E_g + E_p$.

In terms of signs the above data reveals that the plate current may be considered as controlled entirely by the control-grid, operating at full $g_m$ – value, if the actually applied grid voltage is replaced by the grid-control voltage. This control voltage is less than the actually applied voltage because of the minus sign for the second term in equation *16*.

The above discussion as pertaining to the sign of the second term in equation *16* answers the question as to why the screen grid was introduced in the vacuum tube. The unfortunate fact that this sign always is opposite to the sign of the first term may be studied in light of the field distribution at the cathode. When the applied signal makes the grid positive with respect to cathode, the plate goes negative and reduces the change in field-strength produced by the grid. This situation was probably what led W. Schottky to the idea of screening the cathode from the plate by means of a shielding or screening grid, held at a steady positive potential (not to quench the steady plate current). It is well known how Schottky's so designed loud-speaker tube gave inferior results because of secondary-emission phenomenon and first became practical after the introduction of the suppressor or pentode grid.

If the grids are numbered *1* to *3* in the direction cathode plate, and screen grid *2* and suppressor grid *3* carry steady potentials, the complex expression for the rms voltage on control grid *1* may be written as an expansion of equation *19*

$$(E_g)_c = E_{g1} + E_{g2}/\mu_2 + E_{g3}/\mu_3 + E_p\mu, \qquad (20)$$[6]

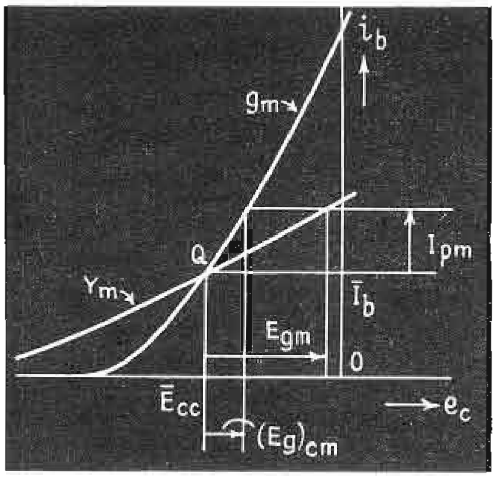
where the two middle terms are assumed to have zero values. The undesirable last term is made negligible compared to the first one by means of the screening (mathematically by means of the high $\mu$ – value). Therefore $(E_g)_c \doteq E_{g1}$ and

$Y_m \doteq g_m$, i.e.,

the pentode utilizes the input signal fully, operating with the high slope of the static characteristic. It is important to realize that Schottky's con-

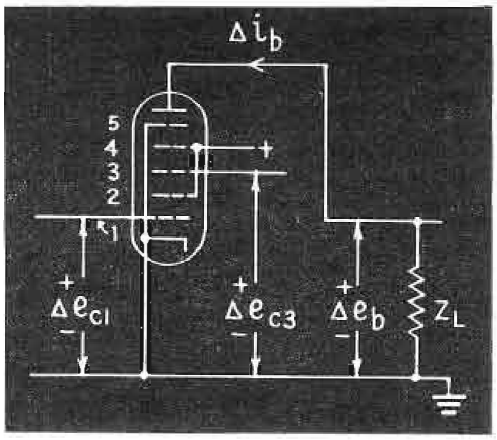
[6]For definitions of the amplification factors, see Appendix 2.

[7]W. Schottky: *Uber Hochvakuumverstärker*, III Teil, Archiv für Elektrotechnik, pp. 299-328; *Band VIII* 1919. In this paper the following statement is of particular interest: "In the question of *freedom from whistling* (prevention of self-excitation of the amplifier circuit) the screen-grid tubes (Schutznetzröhren) with correctly chosen transformers and proper electrostatic shielding (Schutz) do not differ from the other tubes; this question, which initially produced many difficulties in the art, now only plays a subordinated role."




Figures 5 (left) and 6 (right)

Figure 5, plate-current versus signal-grid-voltage characteristics of tube with resistive load. Figure 6, pentagrid mixer as example on multielectrode tube operated with variational voltage on two grids.




tribution was centered on the elimination of the back-effect on the cathode-field by the plate. The introduction of the screen grid did not have anything to do with high-frequencies, as is widely believed. Even Schottky himself did not have much confidence in his tube as a device rendering stability to high-frequency stages[7].

### *Variational Voltage*

Although the above discussion applies to tubes with several grids, the EPC equation is still valid. Now consider the case where not only the first grid, but as well one of the other consecutive grids carries a variational voltage. It may still be possible to apply the EPC equation, but the error is often considerable. For double-control-grid tubes, especially designed and operated to give nonlinearity, the EPC equation breaks down. This is because the tube characteristics are no longer straight, parallel and equidistant. The characteristics in a particular diagram may be straight but not parallel. It is rather interesting to note that the $i_p e_g$ characteristics for a particular control grid may be straight, but nonlinearity still results if the characteristics are spread out like a fan. Perhaps the simplest way of indicating nonlinearity is to say that the tube coefficients are not any longer constants, the transconductance of one control grid being a function of the voltage on the other control grid. This effect may be referred to as the gate-effect.[8]

The same care previously exercised with respect to signs in linear tube circuits may be required in the treatment of nonlinear tubes. The general expansion for a tube with two consecutive control grids with variational voltages $\Delta e_{c1}$ and $\Delta e_{c3}$, Figure 6, may be written

$$\Delta i_b = a\Delta e_{c1} + b\Delta e_{c3} + c\Delta e_{c1}^2 + d\Delta e_{c3}^2 + f\Delta e_{c1}\,\Delta e_{c3} + g\Delta e_{c1}^3 + \dots \quad (21)$$

The coefficients in this total differential are as follows:

$$a = \frac{\partial i_b}{\partial e_{c1}} \quad c = \frac{1}{2}\frac{\partial^2 i_b}{\partial e_{c1}^2} \quad f = \frac{\partial^2 i_b}{\partial e_{c1}\,\partial e_{c3}}$$

$$b = \frac{\partial i_b}{\partial e_{c3}} \quad d = \frac{1}{2}\frac{\partial^2 i_b}{\partial e_{c3}^2} \quad g = \frac{1}{6}\frac{\partial^3 i_b}{\partial e_{c1}^3} \quad \dots (22)$$

With the grid arrangement of Figure 6 and curved characteristics, the actions by the two control grids will not be independent, as the *gate* effect comes into play. The coefficients *e, d, f, g* — are not zero, but if straight-line characteristics are assumed, *c* and *d* become zero. The coefficient *f* still remains, however, the fifth term indicating the nonlinearity due to the gate effect. This coefficient *f* may be referred to as the *nonlinearity coefficient* and indicates to what extent the voltage on one control grid is able to vary the slope of the other control grid. At ordinary frequencies *f* may be treated as a tube coefficient with a certain numerical, positive value, defined from the expression given in *22* in more or less the same way as $g_m$, $r_p$ and $\mu$ were defined for a triode. The sign of the nonlinearity term is therefore determined by the sign of the variational quantities $\Delta e_{c1}$ and $\Delta e_{c3}$. If one of these quantities is externally applied or if it appears as a voltage drop across an insufficiently well bypassed impedance, the plate current contribution providing the nonlinearity is fully determined to its sign. Naturally this presumes that all applied voltages are introduced with given directions.

Rewriting the expansion in equation *21* we obtain

$$\Delta i_b = a\Delta e_{c1} + b\Delta e_{c3} + f\Delta e_{c1}\,\Delta e_{c3}, \quad (23)$$

or, as one possibility

$$\Delta i_b = (a + f\Delta e_{c3})\Delta e_{c1} + b\Delta e_{c3}. \quad (24)$$

[8]H. Stockman, *A Treatment of Non-linear Devices Based Upon the Theory of Related Linear Functions,* Journal of Applied Physics; December, 1943.

[9]H. Stockman, *Superheterodyne Converter Terminology,* Electronics; November, 1943.

The signs of these terms depend upon how the grids are phased with respect to the common frequency a-c sources. In case of sinusoidal variations the parenthesis $(a + f\Delta e_{c3})$ may be represented by a periodically varying signal transconductance $(g_{m1})_{var}$, so that with $b = g_{m3}$

$$i_p = (g_{m1})_{var}\, e_{g1} + g_{m3}\, e_{g3}, \quad (25)$$

where the last term may be neglected. This equation is of special interest when $e_{g1}$ and $e_{g3}$ are instantaneous values of *different* frequencies. This is the case of modulation and frequency conversion, $g_m$, varying with the frequency of the local oscillator. The first term then is a product term involving $e_{g1}e_{g3}$ with *f* determining the amplitude. An expansion of the trigonometric expressions for $e_{g1}e_{g3}$ yields a difference-frequency term,[9] which in conventional design of superheterodyne receivers is the intermediate-frequency component. The symbolic method of representation is now not practical and the sign relations between electrode voltages and plate current terms not of the same interest as in tube circuits operating with all electrodes at a common frequency.

### *Conclusion*

We have seen that the signs of the tube coefficients are the result of originally made assumptions and that various possibilities are open if the original assumptions are changed. Suggestions for such changes have been made. Awaiting improved sign-conventions and standards, the best thing we can do is to adopt the convention that seems best and apply it rigorously. The lack of signs in tube circuits and circuits without tubes as well, makes it difficult for students and engineers to understand important fundamental ideas.

To show the importance of signs, a few simple tube circuits have been discussed with especial emphasis on the relation between plate-current contributions from various electrodes, this being the point where the sign dif-

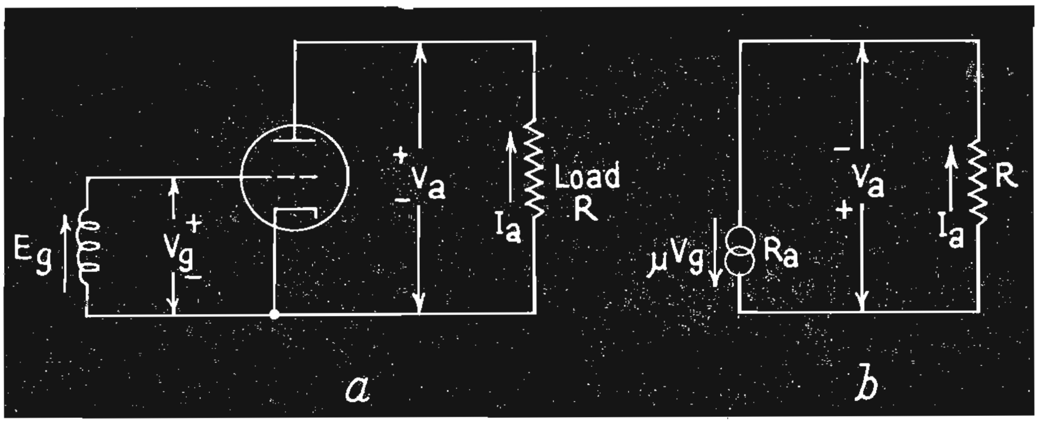



**Figure 7**

**(Appendix I), tube circuit and its equivalent as reproduced from the editorial in *Wireless Engineer***

ficulties are most severe. Conditions when terms of different frequency appear in an electrode circuit have also been discussed briefly.

#### Acknowledgment

The author is very much indebted to Professor E. L. Chaffee, who as a pioneer in this field went all out for signs and made the necessity for signs clear to everybody in the excellent treatments available in *Theory of Thermionic Vacuum Tubes.*

The writer is as well indebted to anyone who supports the idea of signs and is willing to take the pain that is often connected with the efforts of making signs more widely appreciated.

#### Appendix 1

Extract of an editorial of the *Wireless Engineer* by G. W. O. Howe.[10]

In Chaffee's *Theory of Thermionic Vacuum Tubes,* (p. 192) the p-d between the anode and cathode is called $e_p$ and that across the load $e_b$, and it is stated that $de_p = -de_b$, which is strange, since, except for the battery, $e_p$ and $e_b$ are really one and the same, but merely looked at from a different point of view. It is equivalent to the obviously correct statement that $V_{ab} = -V_{ba}$. If one writes $V_a = -RI_a$ then when the current $I_a$ is a positive maximum, the $-dV_a$ must be a negative maximum and the two are necessarily to be regarded as 180° out of phase. If the current is regarded as positive when the grid voltage $V_g$ is positive, then $V_a$ and $V_g$ must be regarded as 180° out of phase. Terman says: 'the plate circuit can be replaced by an equivalent generator of voltage $-\mu e_s$ acting from the cathode toward the plate,' which is, of course, the same as our $+\mu V_g$ acting downwards in Fig. I(b). [Note: Fig. I is here represented as Figure 7.] He expresses it in this way because he reverses the current convention and says "a positive value for $I_p$ means a current flowing in opposition to the steady direct current." He therefore writes $I_p = -\mu E_s/(R_p + Z_L)$, which again looks rather strange. But it may be asked, is there no alternative to these seemingly topsy-turvy conventions? Yes, as soon as one neglects the d-c components, and regards the valve as an a-c generator with an internal resistance of $R_a$ and an equivalent emf $\mu Vg$, one can adopt the usual convention as regards the terminal p-d of a generator, as shown in Fig. I(b). When Vg is a positive maximum, $I_a$ will be a positive maximum and the cathode terminal must be regarded as being at its maximum positive potential. We now have $V_a = RI_a$ without any minus sign and $V_a$ and $V_g$ are in phase. The only point to remember is that the resultant p-d between the anode and the cathode is then the difference between the d-c and a-c components and not their sum. One cannot pretend that the valve, and not the battery, is the source of power without paying the penalty somewhere. For most purposes, however, one is only interested in the a-c components and everything is perfectly straightforward with no jarring minus signs apparently doing violence to Ohm's law.

*G. W. O. H.*

#### Appendix 2: Definitions of Amplification Factors in Equation 20

The total differential for the plate current $i_b$ in a vacuum tube yields

$$di_b = g_{m1}\,de_{c1} + g_{m2}\,de_{c2} + g_{m3}de_{c3} + \ldots\ldots + g_p de_b$$

$$= g_{m1}\left\{de_{c1} + \frac{1}{\dfrac{g_{m1}}{g_{m2}}}de_{c2} + \frac{1}{\dfrac{g_{m1}}{g_{m3}}}de_{c3} + \ldots + \frac{1}{\dfrac{g_{m1}}{g_p}}de_b\right\}$$

$$= g_{m1}\,(de_c)_c$$

If this expansion is compared with the one in equation *20* it is realized that $\mu$ is defined as in a simple triode, so that definition *5* applies

$$\mu = \frac{g_{m1}}{g_p} = -\left.\frac{de_b}{de_{c1}}\right|_{i_b\,e_{c2}\ldots}$$

[10] G. W. O. Howe, *The Phase Convention of Currents and Voltages in Valve Circuits,* The Wireless Engineer, vol. 17, No. 198, pp. 95; March, 1940.

The amplification factors $\mu_2$ and $\mu_3$ may be written

$$\mu_2 = \frac{g_{m1}}{g_{m2}} = \frac{\left.\dfrac{di_b}{de_{c1}}\right|_{e_{c2}}}{\left.\dfrac{di_b}{de_{c2}}\right|_{e_{c1}}} \Bigg|_{e_b\,e_{c3}\ldots} = -\left.\frac{de_{c2}}{de_{c1}}\right|_{i_b\,e_b\,e_{c3}\ldots}$$

$$\mu_3 = \frac{g_{m1}}{g_{m3}} = \frac{\left.\dfrac{di_b}{de_{c1}}\right|_{e_{c3}}}{\left.\dfrac{di_b}{de_{c3}}\right|_{e_{c1}}} \Bigg|_{e_b\,e_{c2}\,e_{c4}\ldots} = -\left.\frac{de_{c3}}{de_{c1}}\right|_{i_b\,e_b\,e_{c2}\,e_{c4}\ldots}$$

These results follow from the general form of the total differential for a function $u = f(x\,y)$, because

$$du = \frac{\partial u}{\partial x}dx + \frac{\partial u}{\partial y}dy = 0$$

yields

$$\frac{\left.\dfrac{du}{dx}\right|_y}{\left.\dfrac{du}{dy}\right|_x}\Bigg|_u = -\left.\frac{dy}{dx}\right|_u$$

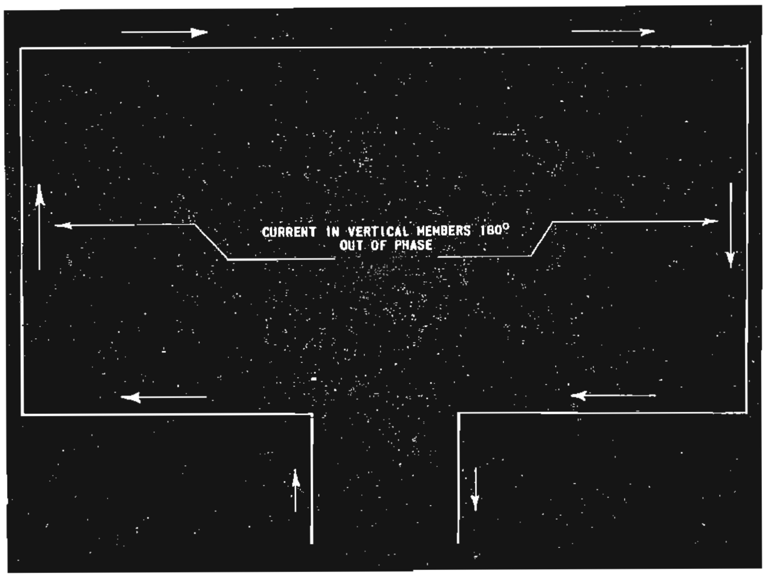
#### Appendix 3: List of Principal Symbols

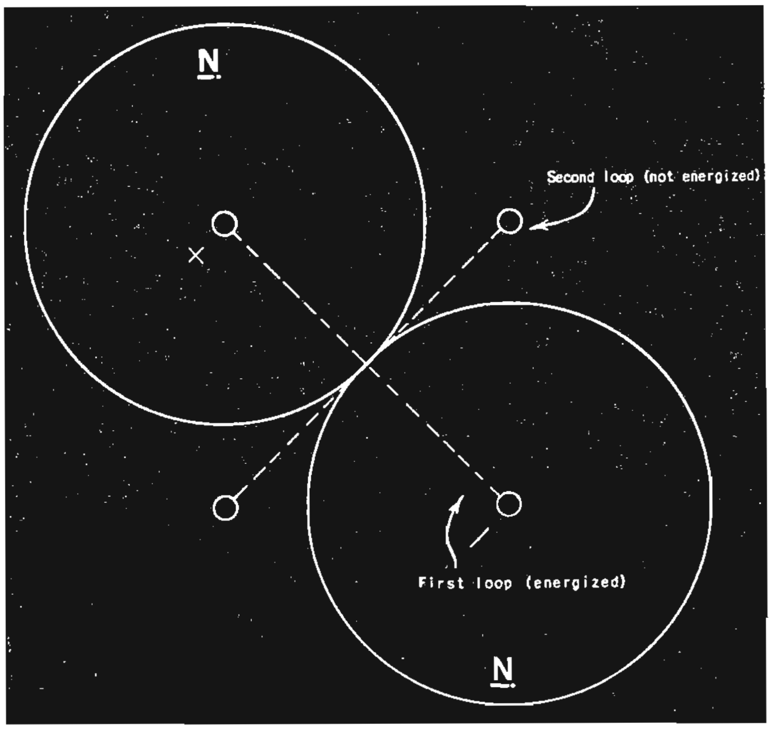
| | |
|---|---|
| $E_{cc}$ | Grid power-supply voltage |
| $E_{bb}$ | Plate power-supply voltage |
| $i_b$ | Total instantaneous plate current |
| $e_c$ | Total instantaneous grid voltage |
| $e_b$ | Total instantaneous plate voltage |
| $e_z$ | Total instantaneous voltage drop across tube load |
| $(e_c)_c$ | Total instantaneous grid control voltage |

*(The above quantities may represent d-c)*

| | |
|---|---|
| $\Delta e_c$, etc. | Finite variations in above quantities |
| $de_c$, etc. | Differentials of above quantities |
| $\partial i_b/\partial e_c$, etc. | Partial derivatives of above quantities |
| $i_p$ | Instantaneous plate current |

(*Continued on page* 104)




Figures 1 (top) and 2 (right)

Figure 1, current distribution in loop. Figure 2, field pattern in the horizontal plane due to one energized loop. The pattern of a pair of towers energized 180° out of phase would be identical. (Small circles represent vertical section of loop; dashes represent horizontal section of loop.)

# DESIGN AND OPERATION OF

*(PART ONE OF A TWO-PART PAPER)*

by CAPTAIN W. G. McCONNELL

Army Airways Communications System

BACKBONE of the modern American system of radio navigational aid for aircraft is the radio range beacon. Scores of these beacons, maintained and operated by the Army Airways Communications System, form a network of well defined *highways of the sky* for all the varied aerial traffic of the Allied military and naval air forces.

We say that the radio range is the background of these airways because this type of beacon is the only one that lays down a definite pathway for the aircraft to follow. The plane itself requires no complicated apparatus, but merely a simple receiver capable of tuning on low and medium frequencies.

The radio range is a transmitting station which provides directional *beams* or courses, usually four in number, radiating from the station like spokes in a wheel. The range station is usually located as near to a landing field as possible, limited primarily by the accident hazard contingent on the rather extensive antenna array.

The range is usually placed on an extension of the center line of a main runway of the landing field, with one *leg* or course of the range leading directly over that runway. At least one, and possibly more, of the other beams are directed along designated routes. Thus, as long as the range signal is properly received on the plane's radio apparatus, the pilot flying the route knows that he is on course and proceeds accordingly.

Within limits, range courses may be adjusted to furnish any desired alignment, but unfortunately they are not completely independent of each other, and the realignment of any one leg necessitates, as a rule, the realignment of all others. Radio ranges of the AACS are originally planned and installed on the basis of best possible operation on one particular route, with two courses more or less secondary in character.

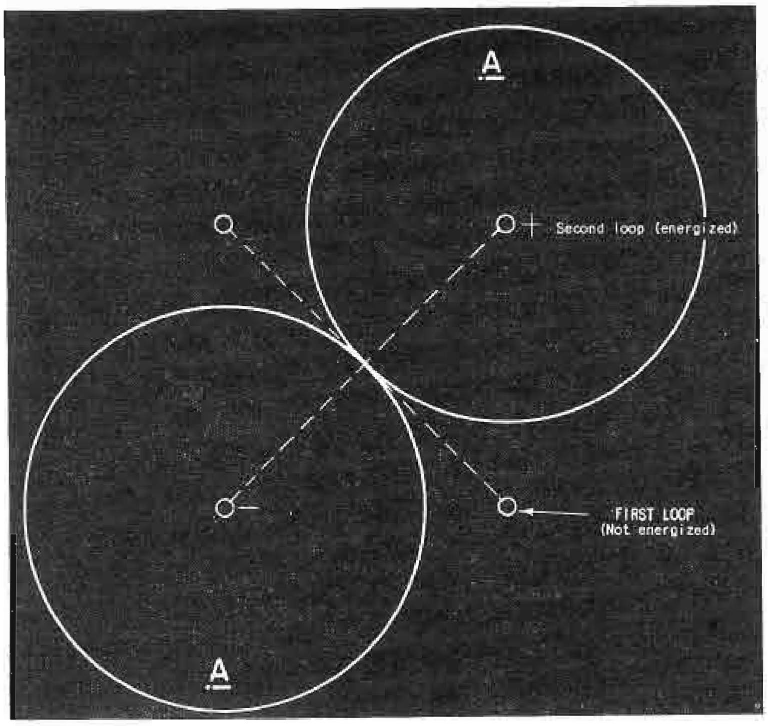
### MRL and SRA Installations

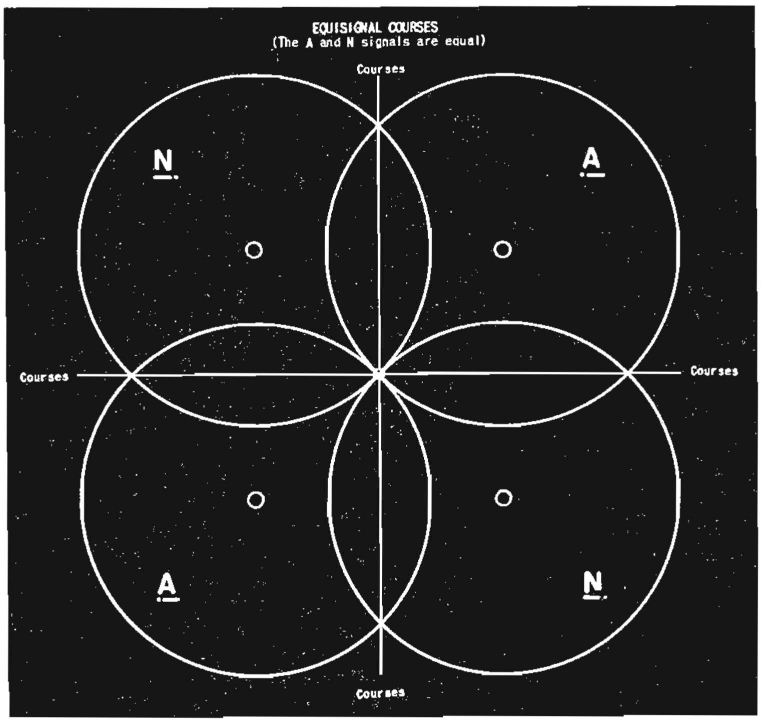
The field pattern of the range beacon is based upon the figure-of-eight pattern produced when two adjacent antennae are energized 180° out of phase with one another. The *MRL* installation utilizes two vertical loop antennae, crossing at the center of each, while the *SRA* type makes use of five insulated vertical steel towers. Aside from this difference, the operation of the two types is quite similar.

Figure 1 illustrates current distribution in a transmitting loop antenna, showing the current opposite vertical elements flowing in opposite directions; that is to say, 180° out of phase. Figure 2 shows the field pattern produced by such antenna. Fig. 3 illustrates the same pattern, rotated 90°, produced by a loop at right angles to the loop in Figure 2.

If these two loops are alternately energized, four regions of steady tone will be produced, radiating from the center of the station at angles of 90°. Obviously if all points along these equi-signal lines can be detected, the lines may be used to fly directly towards or from the station. This is the basic principle on which all radio ranges operate.

For use with any ordinary radio receiver of the proper frequency range, a simple but ingenious method of detecting these courses by ear has been developed. One loop is keyed with the letter *A* (.–), the other with the letter *N* (–.). These signals are so synchronized in the keying mechanisms that the dot of the *A* fits in between the dash and dot of the *N*, and the dash of the *A* fits in between the two *N*'s, as illustrated in Figure 5. As both signals occur with equal intensity, they blend to form a continuous tone,




# RADIO RANGE BEACONS

informing the pilot that he is on course.

Predominance in strength of either the *A* or the *N* signal warns the pilot that he is off course to either side. It has been proven by experience that the average pilot can fly within 1½° of the theoretical true course by this method, the range thus providing a total course of 3° in width. Customarily, the pilot flies the right side of the beam, just as an automobile driver keeps to the right.

The system described above constitutes an aural range beacon, as contrasted with the visual system which by instruments indicates whether or not the plane is on course. The great majority of AACS ranges are of the aural type.

A primary weakness of the loop type range installation is the presence of radiation from the horizontal, as well as the vertical, portions of the loop. This tends to produce false or faulty courses, particularly at night, with the chances of error becoming progressively greater as the distance from the station increases. For this reason, the *SRA* type range is preferred when stations are separated by considerable distances.

The *SRA* range substitutes a pair of vertical steel radiating towers for each loop. Each pair of towers is normally placed 600 feet apart, at the opposite corners of a square approximately 425 feet on each side. The towers are fed by shielded transmission lines, and are so connected that the currents produced in the opposite towers of each pair are 180° out of phase with each other, as in the opposite vertical sections of the loop antenna. Radiating characteristics of the four towers are thus equivalent to those of the vertical elements only of two crossed loops. Since no horizontal radiating elements exist, interference of this type is eliminated, and the courses are more reliable at all distances from the station.

In the early days of the AACS the great majority of range installations were *MRL* facilities. There were several reasons for this, the principal one being the extreme shortage of materials on hand for construction of *SRA* facilities. Another impediment was the lack of trained Army personnel with the technical background and engineering experience to supervise installation and adjustment of *SRA* ranges. However, with the commissioning of trained radio engineers and the cooperation of the Civil Aeronautics Administration, this difficulty is being overcome, and as materials become more available many *MRL* ranges are being replaced with the more reliable and efficient *SRA* type.

While the *MRL range* is equipped with a broadcast antenna for transmission of weather reports and operational information, this facility is subject to one great weakness; the beacon must be interrupted while this broadcast antenna is in use.

This is not true of the *SRA* stations, which are able to operate beacon and broadcast facilities simultaneously, so that the pilot may get all weather and operational information furnished by the AACS without losing the range signal at any time. This simultaneous broadcast is produced in the following manner.

Instead of modulating the transmitter to produce a tone audible to the pilot, as in the case of the *MRL* range, the *SRA* station utilizes two transmitters. One transmitter, energizing the corner towers and producing the figure-of-eight patterns previously discussed, is known as the side-band transmitter. This transmitter is not modulated and will produce no tone in the receiver. Considered alone, it is an unmodulated continuous wave transmitter.

In order to produce a tone and provide facilities for voice broadcasts a second transmitter, known as the carrier transmitter, supplies power to the center tower. The frequency of the tower transmitter differs by 1020 cycles from that of the side-band transmitter, both frequencies being received simultaneously to produce a 1020-cycle tone in the output of the receiver.

Since the carrier power is considerably greater than the side-band power, the amplitude of the signal varies with the amplitude of the side-band. Thus, the figure-of-eight pattern produced by

**[*Illustrations at top of Page*]**

Figure 3 (top, left) and 4 (top, right).

Figure 3, field pattern of second loop. (Small circles are vertical section of loop; dashes represent horizontal section of loop.)

Figure 4, field patterns of two loops alternately energized. (Small circles represent vertical radiating members.)

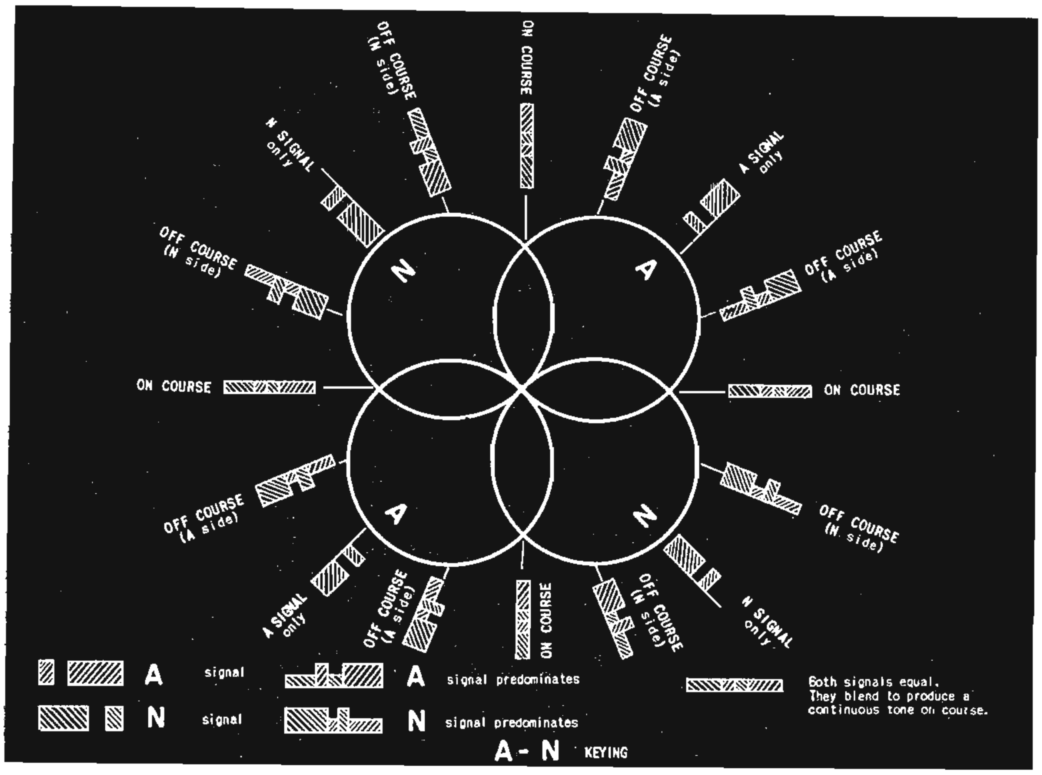



Figure 5

the side-band transmitter governs the tone received by the aircraft radio.

The ratio of side-band power to carrier power is about 3 to 10, affecting approximately 30% modulation of the carrier. Since the carrier is only 30% modulated by the side-band signal, the remaining 70% of the carrier power is available for voice modulation.

Voice modulation is accomplished in the normal manner. The audio-power is applied to a modulator in the carrier transmitter, which modulates this transmitter up to 70%, and leaves the remaining 30% available for modulation in space by the combination of the radiated side-band power with the carrier power. Thus weather and operational broadcasts can be sent over the carrier transmitter without disturbing range beacon operation. While the beacon signal is directional, the broadcasts are non-directional, since the carrier has a circular pattern. Figure 6 illustrates the field patterns of an *SRA* station.

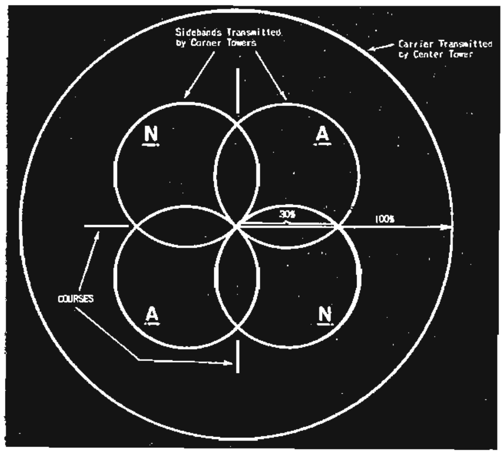



Figure 6
Field pattern of SRA station.

In the aircraft a band-pass band-elimination filter separates the range signal from the voice signal so that they may be heard separately. By means of a headset whose earpieces are wired separately to an instrument board switch, the pilot connects one earphone to the range and the other to the voice portion of the filter, or, if he wishes, both to range or to voice. When the airport operator broadcasts weather information he does so without disturbing the range signals.

If the loops of an *MRL* station could be rotated about the station, the courses would rotate accordingly, and in some early English designs this actually occurred. However, (it can be shown that) if both loops are simultaneously energized with equal currents at the same frequency, the axis of the figure-of-eight pattern thus produced bisects the angle between the two loops. If the four towers of an *SRA* installation are equally energized the same pattern results, with the axis of the figure-of-eight pattern lying in the quadrant between the two towers that are in phase. This is illustrated in Figure 7.

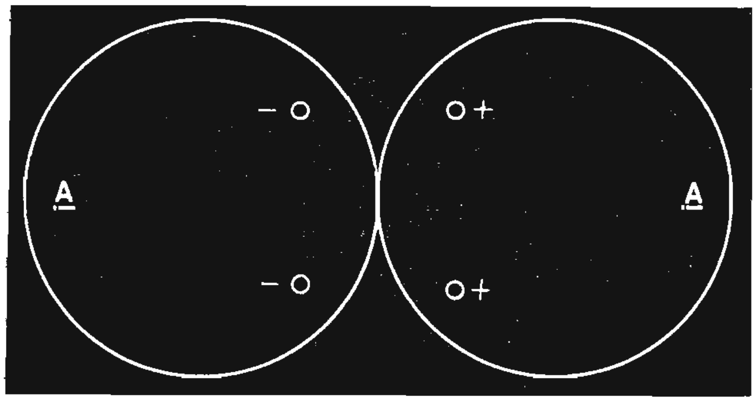



Figure 7
Field pattern rotated 45°, first primary energized. (Small circles represent radiating element goniometer at 45°.)

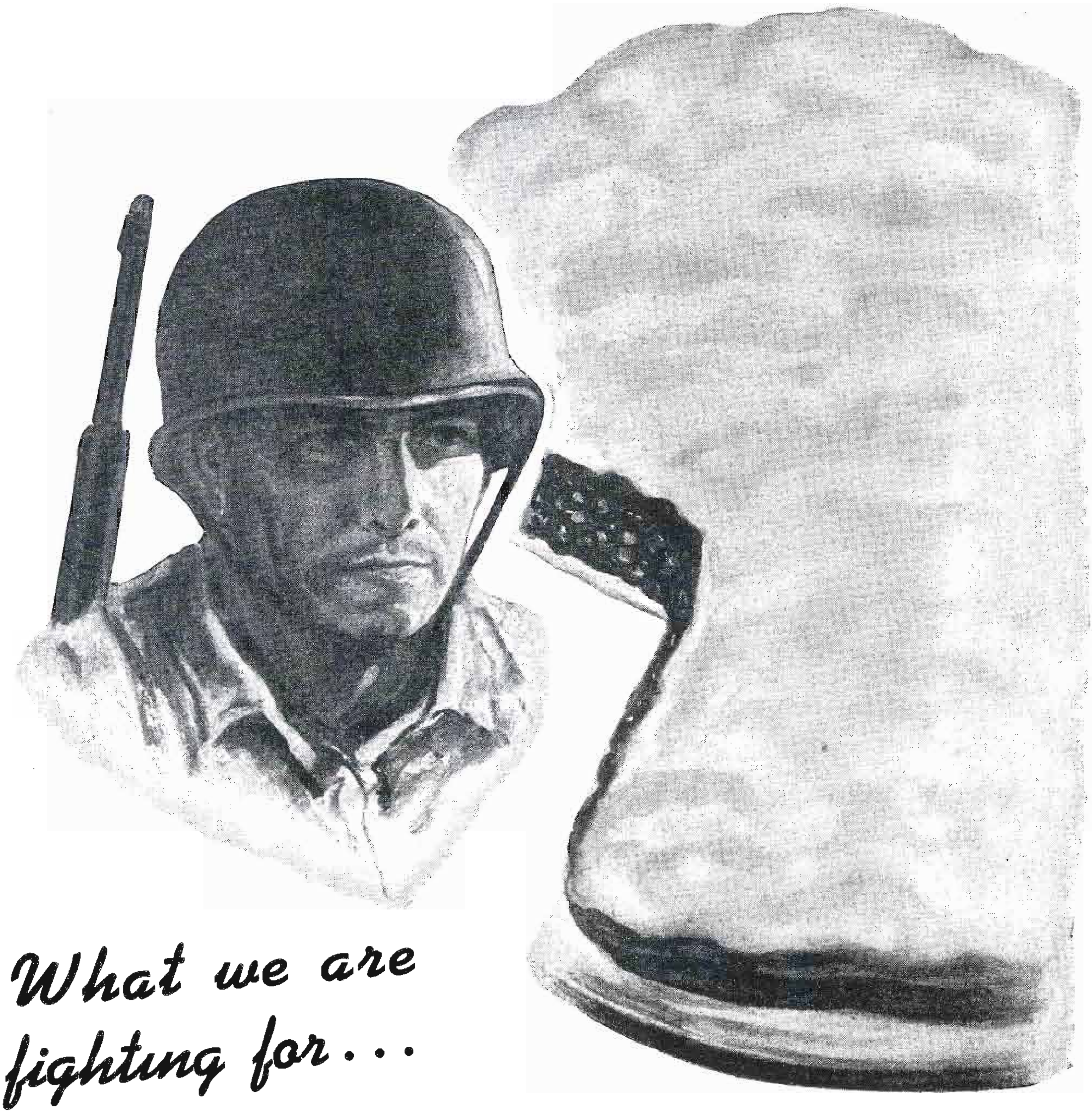
If the phase of the energy fed to one loop or pair of towers reverses, the figure-of-eight pattern is rotated 90°, as illustrated in Figure 8. If the loop or towers are fed in this manner, the courses lie over the antenna as indicated in Figure 9. In effect, the courses have been rotated 45° from the position they assume when each loop or pair of towers is energized separately.

It can be shown also that as the current in one loop or pair of towers is varied with respect to the current in the opposite loop, the figure-of-eight pattern, and consequently the courses, will rotate in the direction of the loop or pair of towers containing the greater current. Figure 10 illustrates, by means of a vector diagram the manner in which this occurs.

### The Goniometer

Advantage has been taken of this phenomenon in order to permit rotation of courses about the station without rotating the antennae. This is accomplished by means of a goniometer, having two secondaries, each of which is connected to one loop or pair of towers. These secondaries are wound perpendicular to each other, as are the two primaries. The link circuit relay connects the *A* signal to one primary, while the *N* is connected to the other.

When the goniometer is so adjusted that one secondary is parallel to and coupled with *A*, it is then perpendicular to primary *N*. The other secondary is then parallel to and coupled with primary *N*, and perpendicular to primary *A*. Thus the *A* energy and the *N* energy are each



# *What we are fighting for . . .*

A war correspondent in the Solomons asked a tired marine what he thought he was fighting for. The marine's face lit up.

"Gosh," he whispered, "what I'd give for a piece of blueberry pie!"

To that marine "blueberry pie" summed up the democratic way of life . . . the dates . . . the movies . . . the ball games . . . home cooking . . warm family ties . . . and the joy of walking in the woods without fear of a lurking sniper.

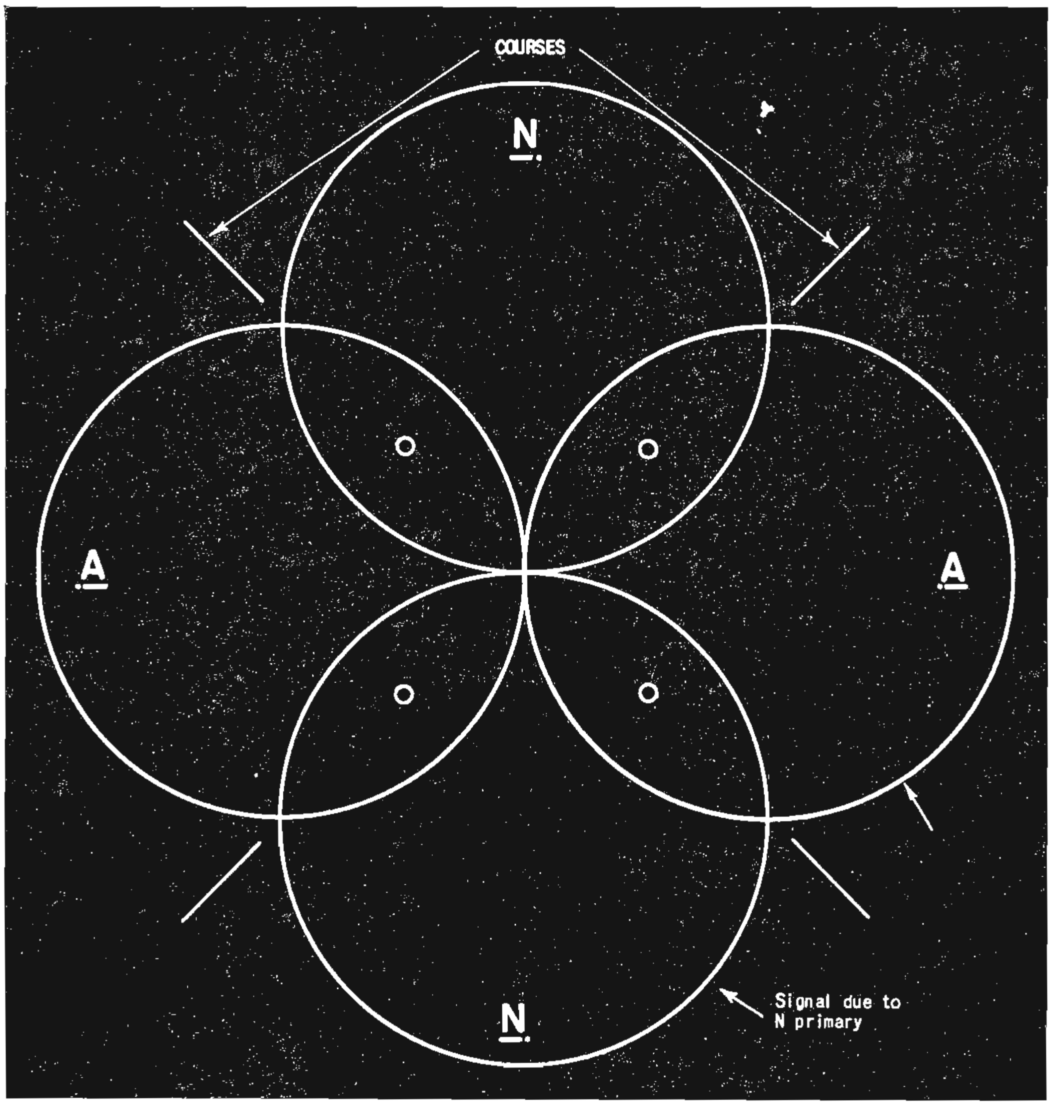
Homely things like these are what we are all fighting for . . . the soldier in his job . . . you in your job . . . we in our job of building dependable Kenyon transformers as fast as we know how.

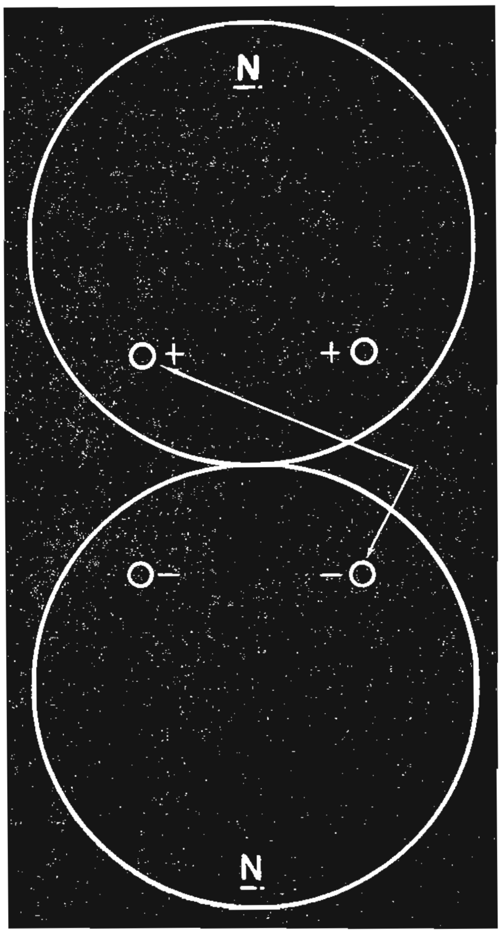
Most of us can hurry the day when that fighting marine can have his pie. We can buy an extra dollar's worth of bonds this week . . . give a pint of blood every few months . . . save scrap metal, rubber and rags . . . and we can stay on the job every day, all day.

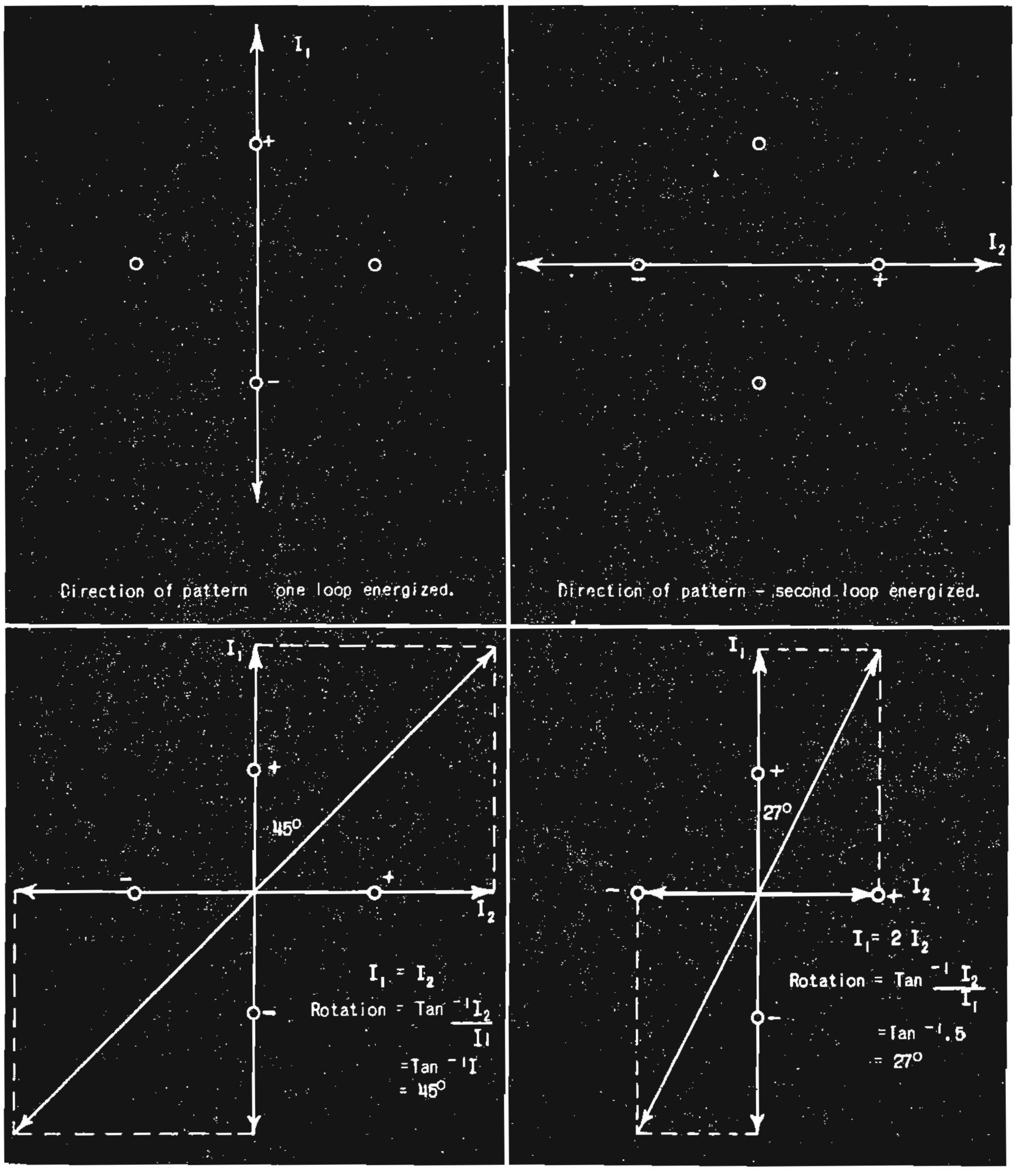
Let's not let the boys wait for their pie a minute longer than they must.

*THE MARK OF EXCELLENCE*

**KENYON TRANSFORMER CO., Inc.** 840 BARRY STREET NEW YORK, U. S. A.



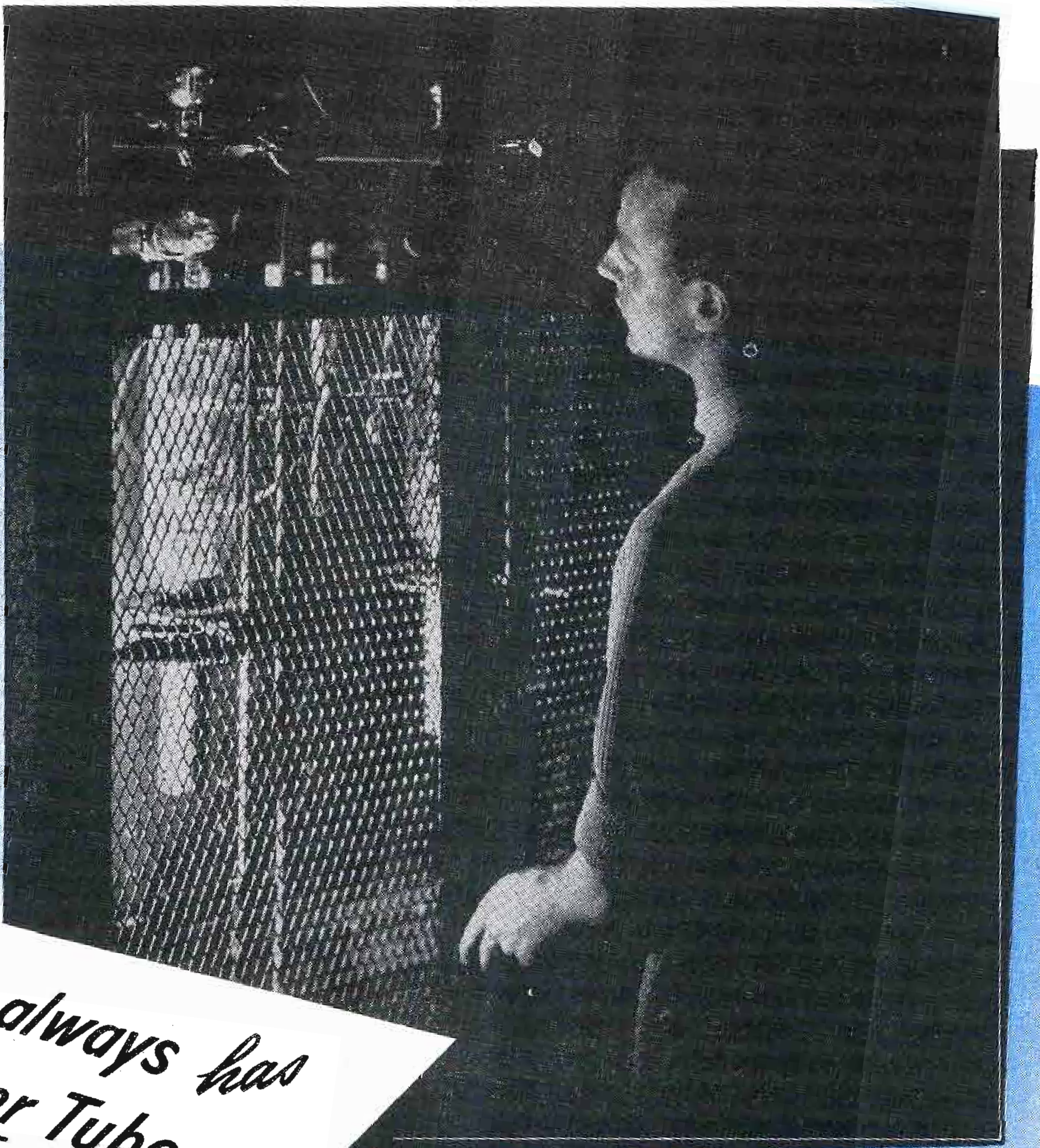




Figures 8 (top), 9 (left, top) and 10 (left, below)
Figure 8, field pattern rotated 45°, second primary energized. Phase of one antenna system has been reversed from Figure 7. (Small circles represent radiating element goniometer at 45°. Figure 9, courses secured with goniometer at 45°. (Small circles represent radiating element goniometer at 45°.) Figure 10, vector diagrams illustrating course rotation. At bottom left, vector resultant, both loops simultaneously energized by equal currents. Resulting pattern is rotated 45°. At bottom, right, vector resultant, both loops simultaneously energized by unequal currents. Resulting pattern is rotated by an angle whose tangent is equal to the ratio of two currents

coupled into one antenna only. With this adjustment, the axis of the figure-of-eight pattern lies along the line of the antenna, and the courses lie midway between the antennae, as shown in Figure 4.

With the goniometer set at 45°, each primary couples equally to both secondaries. However, when the relay switches from one primary to the other, the phase of one antenna is reversed (see Figures 7 and 8). One primary then produces a figure-of-eight pattern whose axis lies midday between the antennae, while the pattern produced by the second primary will be at right angles to that pattern. Rotation of the goniometer primary from the 45° position toward zero or 90° increases the energy in one antenna while decreasing it in the other, rotating both figure-of-eight patterns, and consequently the courses. The angle of displacement of the courses is equal to the number of de-



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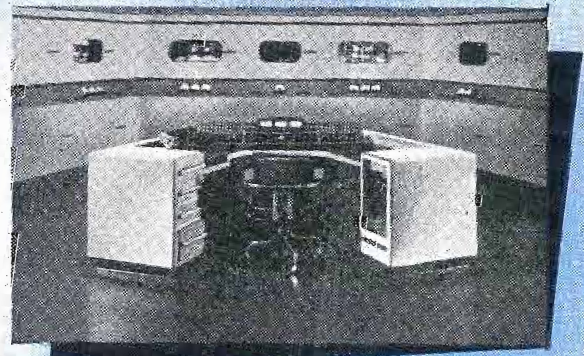

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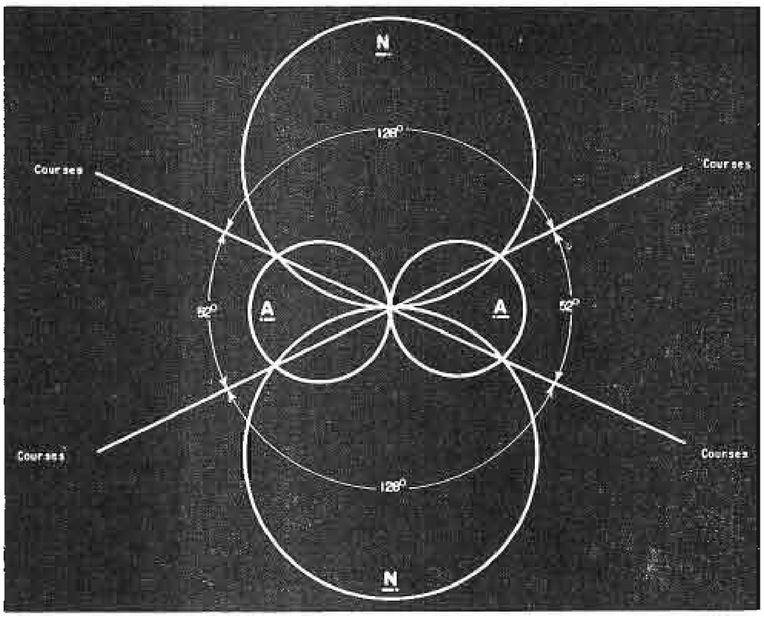
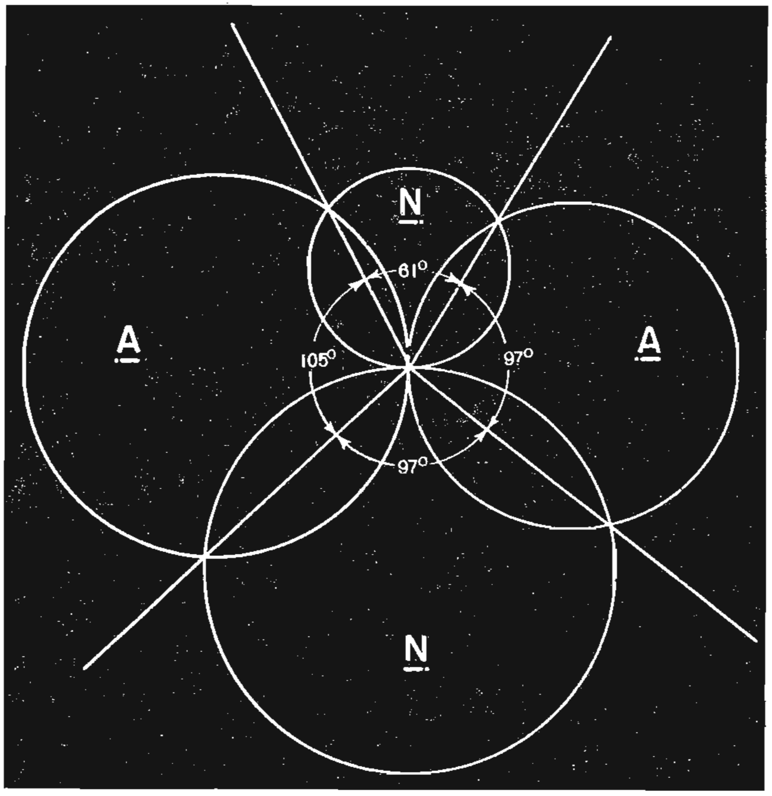



**Figures 11 (top) and 12 (right)**

Figure 11, field pattern illustrating course shifting. Power in *A* primary has been reduced, shifting the courses towards the *A* zone. Courses are still straight through the station, but are no longer perpendicular to one another. Figure 12, field pattern illustrating course bending. Figure-of-eight patterns have unequal lobes to secure course bending. Current in opposite radiators no longer 180° out of phase.




grees of rotation of the goniometer. If the goniometer has been properly designed, the total power drawn from the transmitter will remain constant regardless of the relative position of primaries and secondaries.

Although the goniometer facilitates rotation of all four courses of the range, it offers no means by which the courses may be varied with one another; i.e., each course remains at an angle of 90° with adjacent courses. Variations in the respective positions of opposite pairs of courses may be accomplished in the following manner.

If the power fed to primary *A* is reduced, figure-of-eight patterns as shown in Figure 11 will result. The effect is to rotate each pair of opposite courses in relation to each other and to true directional bearing, but the opposite courses still remain separated by 180°; i.e., they form a straight line through the center of the station.

This effect, known as course shifting, or squeezing, is created by the insertion of a resistance pad in the *A* primary of the goniometer, absorbing a portion of the transmitter energy and proportionately reducing the radiated energy. Similarly, to shift courses toward the *N* zones, the resistance pad would be placed in the *N* primary.

The bending of opposite courses so that they deviate from a straight line through the station is sometimes necessary. This bending, as illustrated by Figure 12, is effected by changing the radiation pattern so that the two opposite lobes of a figure-of-eight pattern are of unequal amplitude. In the case of an *SRA* station this result will be secured if the current in opposite towers is less than 180° out of phase.

The manner in which this phase changing occurs may be understood by examining Figure 13. In order to make this adjustment, we resort to the use of artificial lines. An artificial line of some known length, such as 20°, is inserted between the goniometer secondary and each of the transmission lines to the four towers. If the phase difference required between two towers is 170° rather than 180°, the artificial line to one tower is increased to 25°, while that to the opposite tower is decreased to 15°, thus producing a total difference of 10° between the line lengths. This difference will subtract from the difference in phase between the two towers.

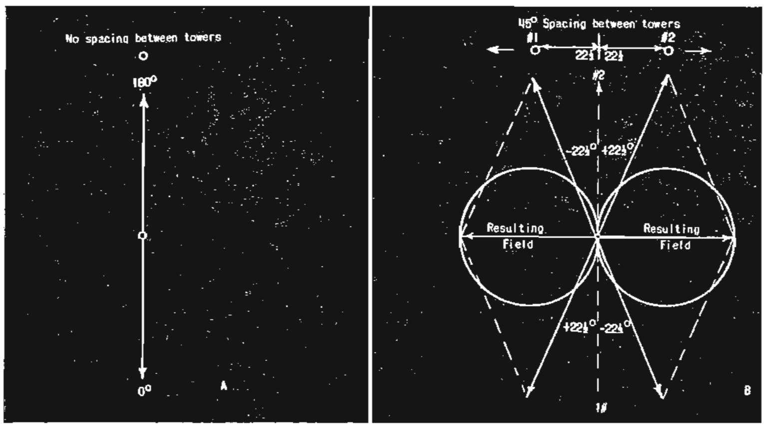
The combination of course bending, course shifting, and goniometer adjustment enables almost any desired course alignment to be realized.

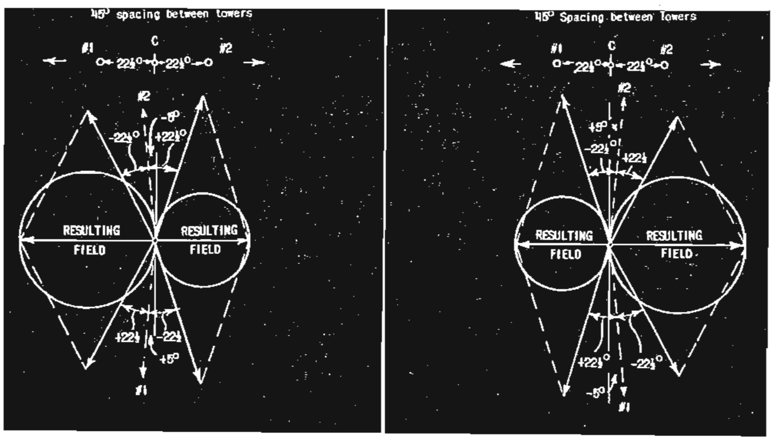
Since the configuration of a loop antenna fixes the phase difference at a constant 180°, it is necessary to adopt some other means of bending the courses of an *MRL* beacon. This is accomplished by the use of an auxiliary antenna, generally the same antenna used for broadcasting weather reports. Normally erected precisely in the center of the two loops, the energy coupled into this broadcast antenna by the opposite vertical sections of the loops will cancel and no current from these sources will flow in the broadcast antenna.

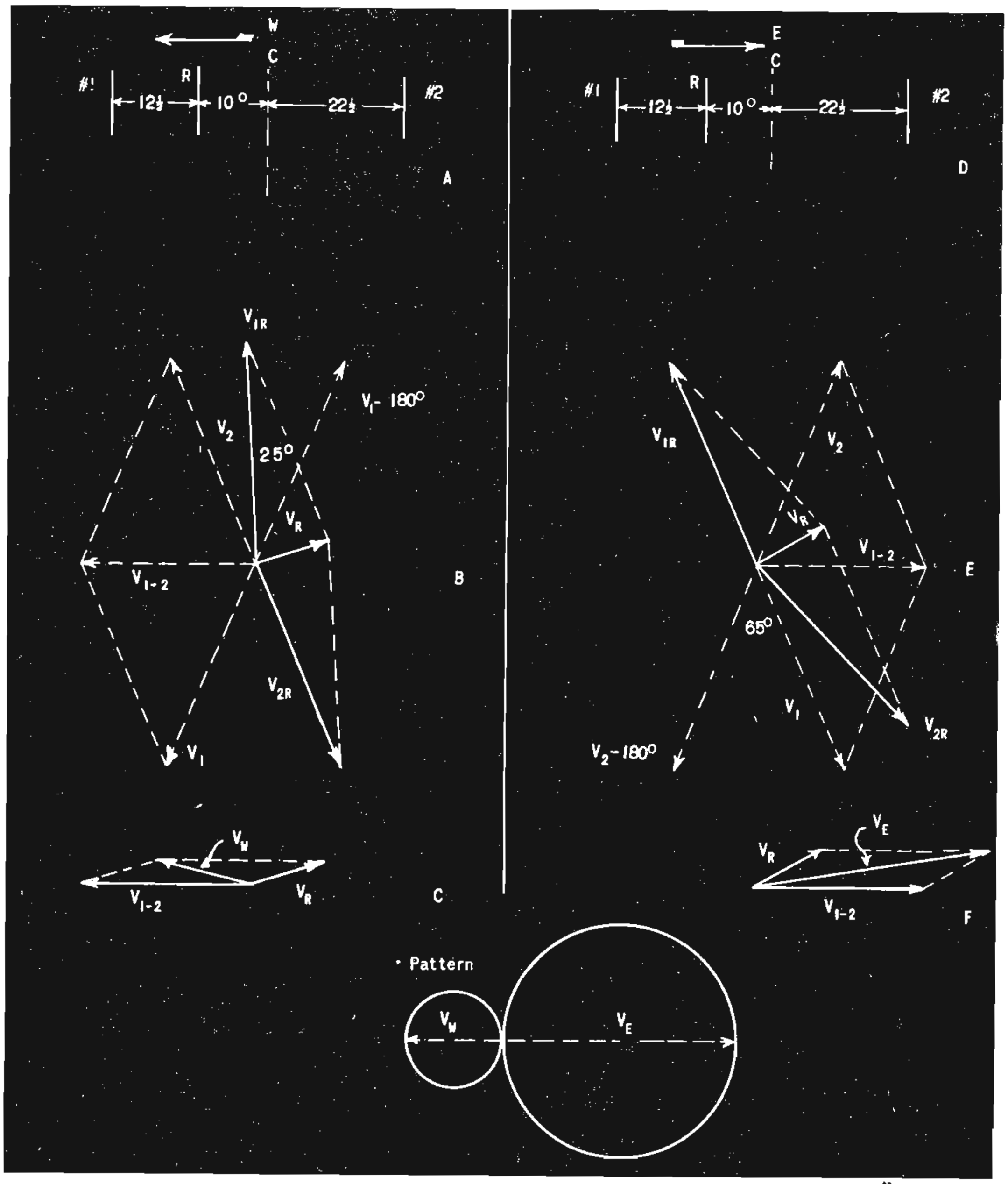
However, if the broadcast antenna

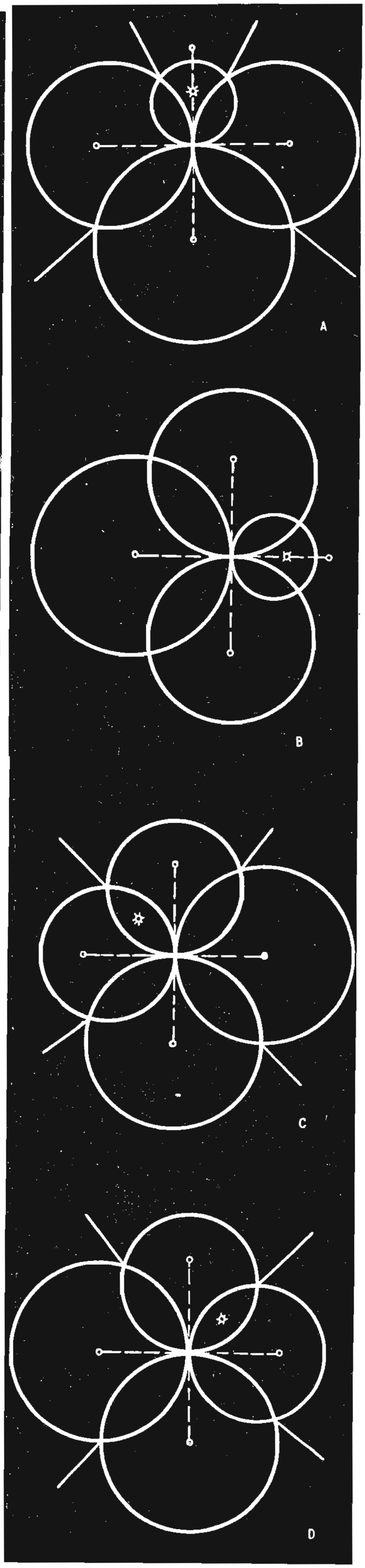
Figures 13 (left, below) and 13a (right, below)

Figure 13, effect of tower spacing in establishing pattern. In A, towers 180° out of phase; vectors cancel, no field. In B, tower 180° out of phase. Tower *1* advanced 22½° in direction of *1*; retarded 22½° in direction of *2*. Tower *2* retarded 22½° in direction of *1*; advanced 22½° in direction of *2*. Pattern is symmetrical. Figure 13a, effect of adding variation of transmission line length to tower to distort pattern. In C, towers 170° out of phase. *1* advanced 5°, *2* retarded 5°. Pattern increased in direction of *1*; decreased in direction of *2*. In D, towers 170° out of phase. *1* retarded 5°; *2* advanced 5°. Pattern increased in the direction of *2*; decreased in direction of *1*.






is moved a few feet away from the center pole, it will be coupled closer to one section of the loop than to the other and current from the loops will flow therein. The magnitude and phase of this current will affect the pattern radiated by the loops, as illustrated in Figures 14 and 15. The final effect is similar to that obtained by changing the artificial line length in the *SRA* antenna system.

So far we have talked about the range principally from a structural point of view. Since it is, after all, designed, maintained, and operated solely for the safety and protection of the men flying the airways, let's conclude with the picture of the range as it is used by these flyers. Remember that there are two types of range maintained and operated by the AACS, just as by the CAA. In both instances the *SRA* offers a greater margin of safety and will some day outnumber the *MRL* installations. Let's have a look at each of the two types from the airman's point of view.

The pilot flying one of the AACS *MRL*-radio ranges will hear a steady tone, if he is on course. This tone is interrupted approximately every thirty

Figures 14 (top) and 15 (right)

Figure 14, effect of course bending antenna (reflector). Figure 15 shows patterns secured due to presence of course bending antenna (reflector). Dashes between small circles indicate loop; asterisks are course bending antenna.

seconds by the identifying call letters of the range station. When the aircraft is off the course, the pilot receives predominantly an *A* or an *N* signal, depending on which quadrant he is in.

At either thirty minute or hourly intervals the range transmitter operator breaks in on these range signals with weather information sent out over the broadcast antenna. The result is, of course, that during this transmission of weather, or other information (since special instructions and messages are authorized for transmission on the range frequency) the pilot must proceed with no accurate check on his direction. He thus runs the risk of getting off course and being unable to pick up the beam at the end of the weather broadcast. In

(*Continued on page* 104)

# *Keeping Sea Lanes* FREE *Lanes*

*M*ore amazing than fiction are the dashing exploits of PT boats. In a war to keep free the sea lanes of the world, these combat vessels streak into action and unleash a group attack that's packed with power and punch. One reason they maneuver so successfully: the lanes of communication are kept free. Vital radio messages from boat to boat are protected against noisy local intereference.

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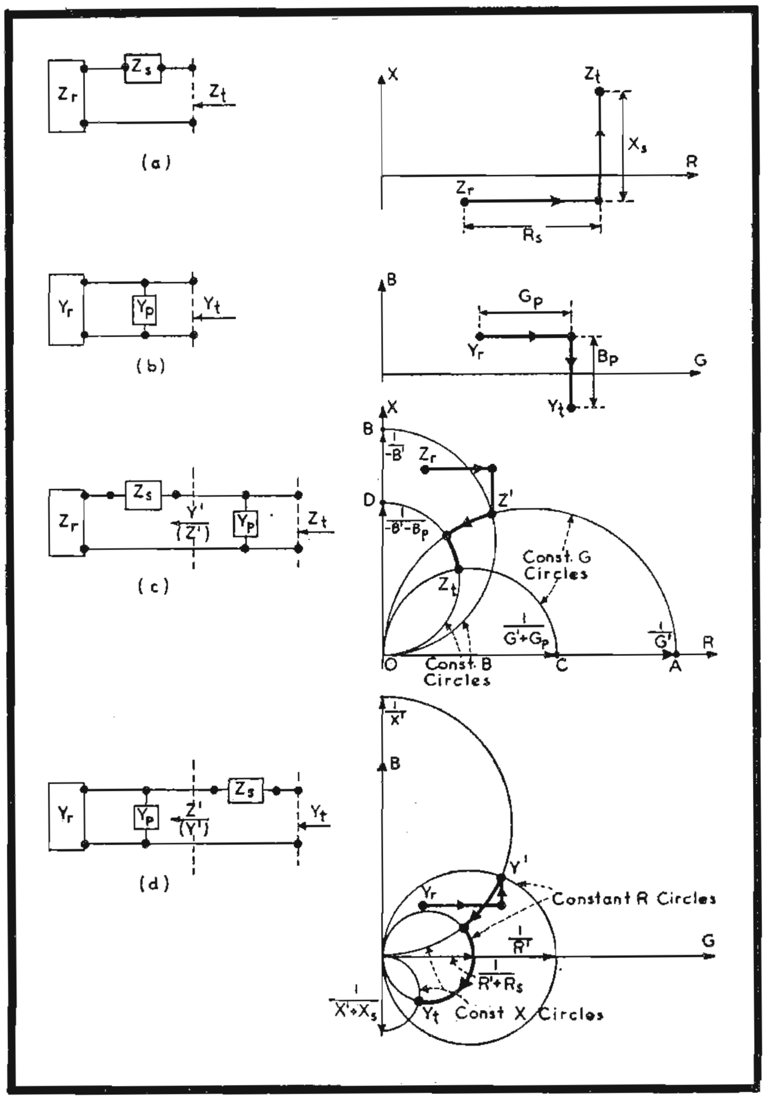
**CAPACITORS AND RADIO NOISE-SUPPRESSION FILTERS**

# IMPEDANCE TRANSFORMATION

*(PART ONE OF A TWO-PART PAPER)*

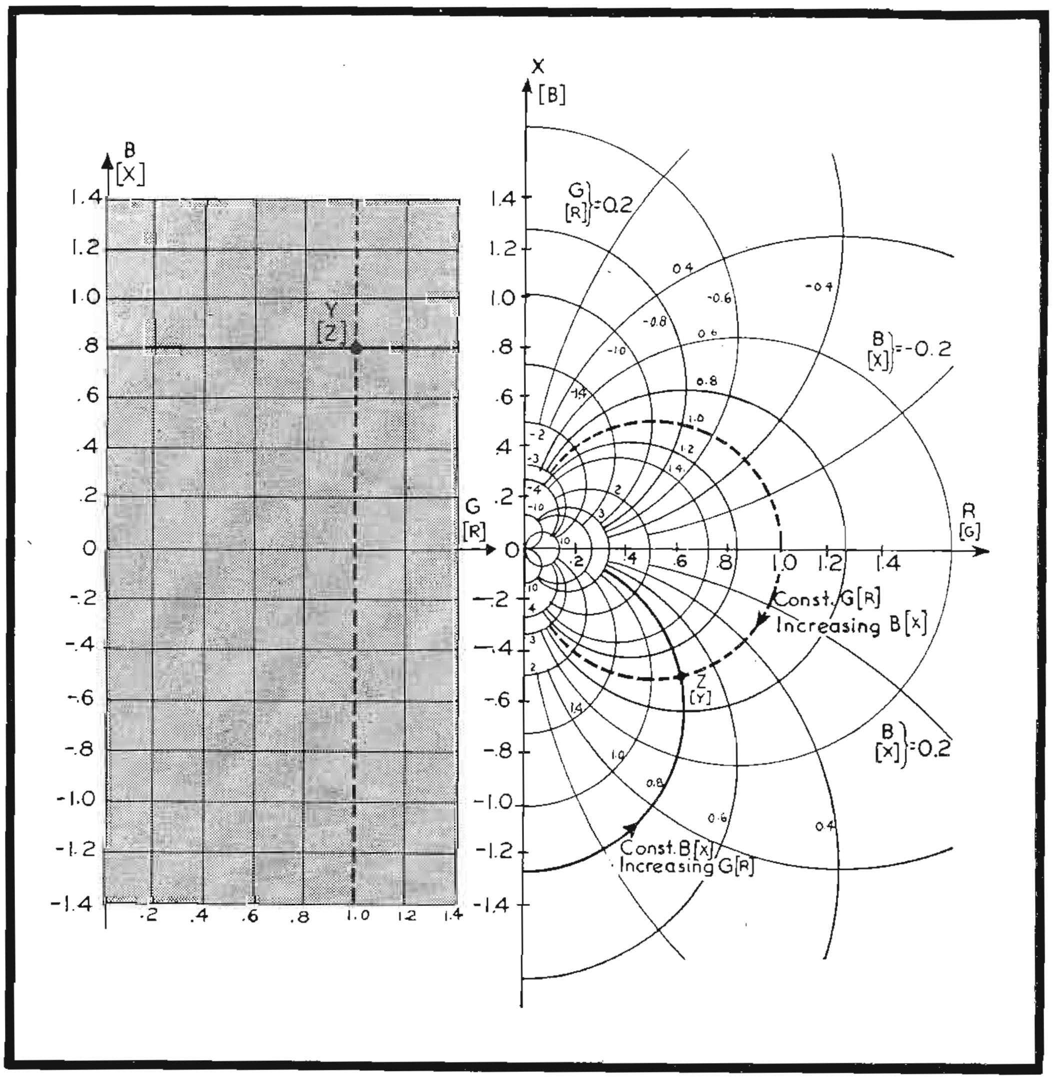

**by PAUL J. SELGIN**

**Instructor, Electrical Engineering, Polytechnic Institute of Brooklyn**


Figures 1 (left) and 2 (below)

Figure 1 offers a geometric representation of branch addition. In (a) we have addition of a series branch $Z_s = R_s + jX_s$. *Impedance point* follows line of constant $X$ a distance $R_s$; line of constant R, a distance $X_s$. In (b) is shown the addition of a shunt branch $Y_p = G_p + jB_p$. *Admittance point* is used. In the example, $B_p$ is negative. In (c) we have the addition of branches in series and shunt. Impedance point follows lines of const. $X$, const. $R$, const. $G$, const. $B$ in succession. Point Z′ is obtained as in (a). To continue construction: draw circles through origin and Z′, with centers on axes. Measure $\overline{OA}$, $\overline{OB}$, and compute their reciprocals. Add $G_p$ to $\frac{1}{\overline{OA}}$, $-B_p$ to $\frac{1}{\overline{OB}}$. Reciprocals of sums are diameters of new circles. In (d) we have the addition of branches in shunt and series. Admittance point is used: both representations are equally suitable in this case and to (c). The construction is as in (c) except for dual substitution (R for G, X for B, etc.). $X_s$ is positive in this example: hence const. $R$ circle is described in c-w direction. Figure 2 shows a map of the inverse function, illustrating the inversion of orthogonal parallel lines into orthogonal families of circles. The inverse function map may be used to find $B$ and $G$ for known values of $R$ and $X$, or vice versa (bracketed notation). The unit of $R$ and $X$ is $10^n$ ohms; that of $B$ and $G$, $10^{-n}$ mhos.




THE chief purpose of impedance transformation is that of insuring a maximum flow of electrical power from a given *source* or *generator* to a given *load* or *receiver.*

All impedance transformation problems call for an *impedance transforming network,* also called *coupling network* or *coupling,* of suitable characteristics. One of the requirements of this network is invariably that of *low dissipation,* for evident reasons. Other requirements may vary depending on the type of problem. These additional requirements are predicated on the desired variation of transmitted power (and, occasionally, phase angle) with frequency.

### Classification

A rough classification may hinge upon the extent of the frequency range over which maximum power is desirable. In order of increasing complexity, we have the following types of impedance transformation problems:

***The coupling problem.*** This is the problem of obtaining maximum power

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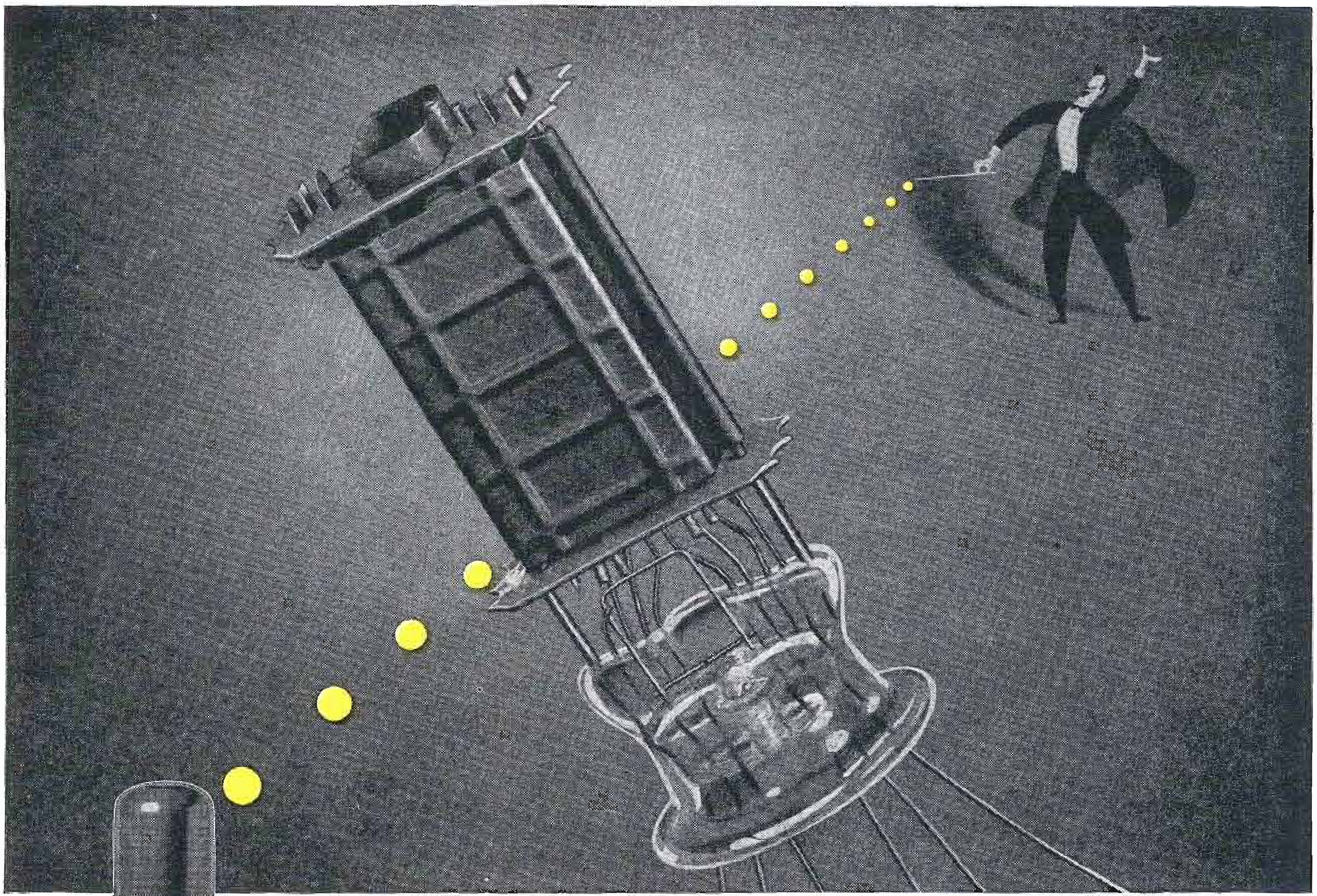
Mathematical statements appearing in this article are presented without proof.



# Metal Magic!

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In metallurgy, as in other sciences related to tube making, National Union is helping to push back the frontiers of electronic knowledge. And in the war record of National Union tubes you will see how well this scientific approach to tube building is paying off. For better tubes, after the war—*Count on* National Union.

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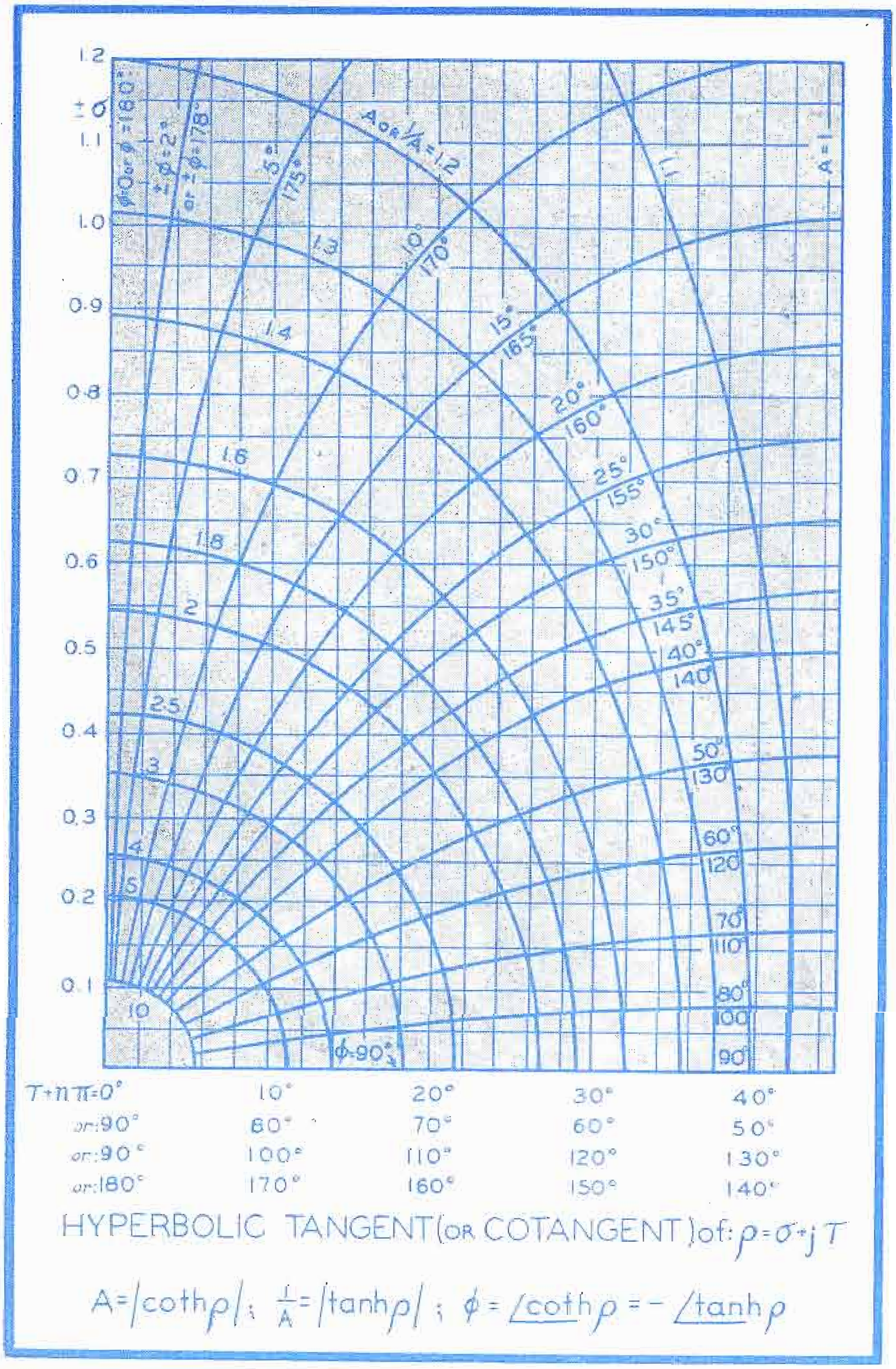



Figure 3

flow from a given source to a given load at some definite value of frequency. Transmission at other frequencies is either unimportant or undesirable; in the latter case, *selectivity* is a requirement.

Often, the coupling has to be made adjustable, so that the transmitted frequency may be changed from time to time. We have then a *tuned coupling* or *tuner*.

The problem of coupling stages of radio frequency amplification is a variation of the coupling problem. In this case, maximum voltage rather than maximum power is the object, and a large part of the source power is absorbed in the coupling.

The coupling problem is associated with the transmission of *carrier* frequencies, hence the operating frequency is generally high. At these frequencies, the reactive components of source and load impedances are apt to be high, and must be taken into account. In addition, careful design is required to avoid capacity effects. At u-h-f, distributed structures, primarily transmission lines, must be used.

***The matching problem.*** The only difference between this and the coupling problem is that either the source or the load, or both, are replaced by the output or input end of a long transmission line. The problem calls for a network which will *match* the line to its terminations. As the characteristic impedance of lines is practically a pure resistance, particularly at high frequencies, this insures maximum power flow.

The matching problem may be regarded as a particular case of the coupling problem, and handled in the same way.

***The transformer problem.*** This problem arises when the transmitted power is to be kept uniformly high over a wide frequency range, and source and load are resistive, but of different values. This is essentially an *audio frequency* problem, solved by close-coupled inductive transformers. However, this type of problem is not uncommon at higher frequencies.

***The filter problem.*** This is the most complex of all impedance transformation problems. Filters are generally inserted between equal resistive terminations, within the *transmitted range* of frequency, and therefore they must have little or no impedance transforming action. Outside this range, they must transform the load impedance into a value approaching a pure reactance, so as to cut down the power flow to a low specified value.

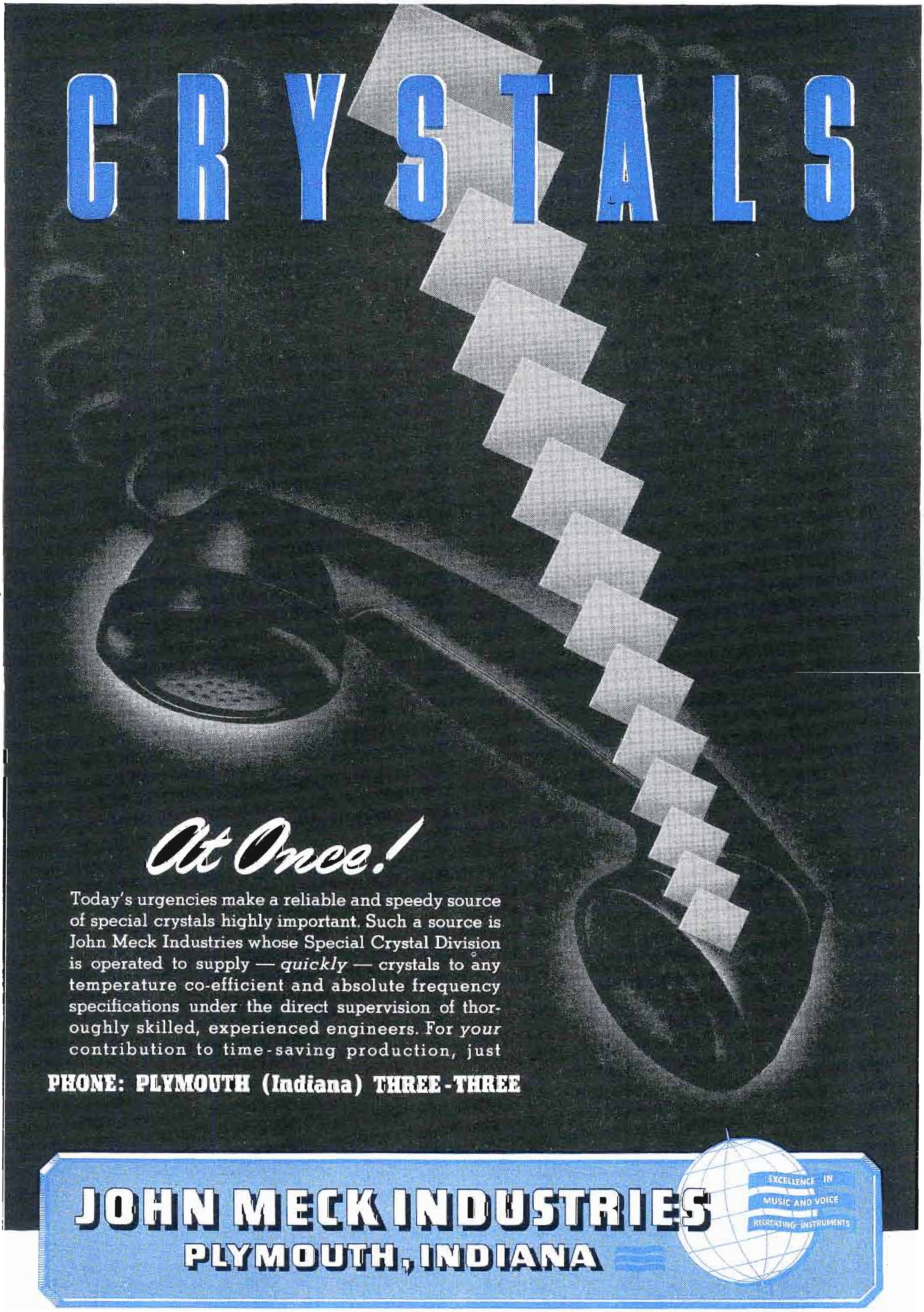
The design of filters is not generally carried out on the basis of their impedance transforming action. For this reason, the filter problem is seldom associated with problems of the first three presented. Yet the distinction between a coupling network and a band pass filter, for example, is not very sharp. Both operate on the same principle.

### Condition for Maximum Power Transfer

This problem can be analyzed in the following way. Suppose we have a generator of a-c power, of internal impedance $Z_g$, and a load or receiver of impedance $Z_r$. For what value of $Z_r$ does $P$, the power transmitted to the load, have maximum value? The answer is well known, although it is not stressed sufficiently in the basic literature on alternating currents. The *condition for maximum power transfer* is simply that $Z_g$ and $Z_r$ must be conjugate complex numbers. Or, in symbols:

$$R_g = R_r$$
$$X_g = -X_r$$

Now suppose the load impedance does not satisfy the above. In order to obtain maximum power flow, we must modify, or *transform* this impedance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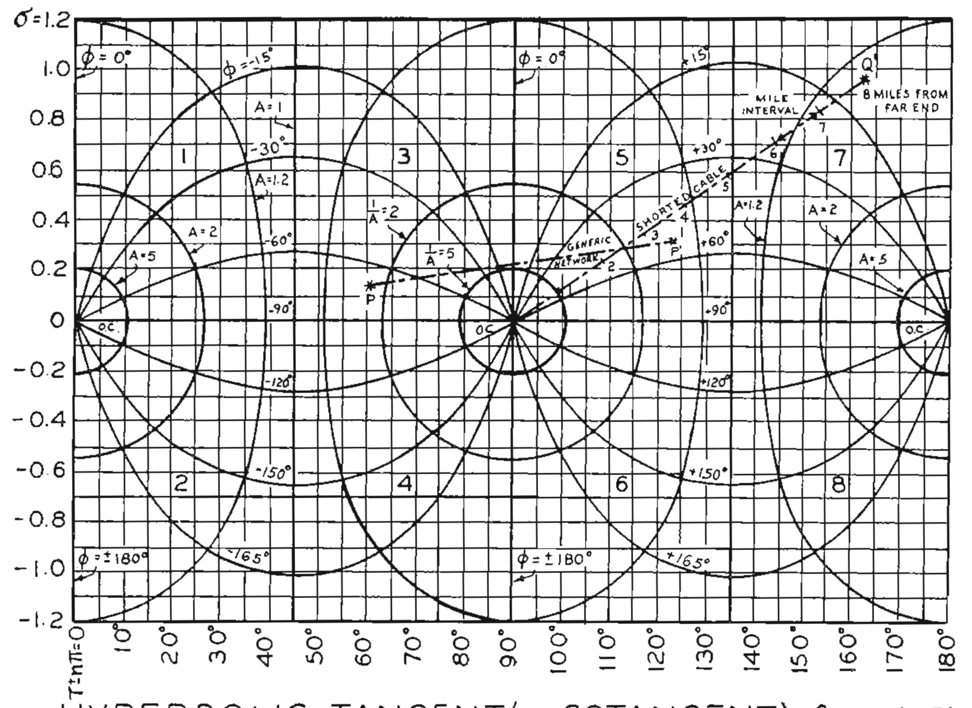



HYPERBOLIC TANGENT (OR COTANGENT) of: $\rho = \sigma + jT$

$A = |\coth \rho|$ ; $\frac{1}{A} = |\tanh \rho|$ ; $\phi = \angle\coth \rho$ ; $-\phi = \angle\tanh \rho$

RANGE SELECTION TABLE

| RANGE of $T \pm n\pi$ | RANGE of $\sigma$ | QUADRANT # | RANGE of $\phi$ | RANGE of A |
|---|---|---|---|---|
| $0 < T < 45°$ | $\sigma > 0$ | 1 | $0 > \phi > -90°$ | $A > 1$ |
| " " | $\sigma < 0$ | 2 | $-90° > \phi > -180°$ | " " |
| $45° < T < 90°$ | $\sigma > 0$ | 3 | $0 > \phi > -90°$ | $A < 1$ |
| " " | $\sigma < 0$ | 4 | $-90° > \phi > -180°$ | " " |
| $90° < T < 135°$ | $\sigma > 0$ | 5 | $0 < \phi < 90°$ | " " |
| " " | $\sigma < 0$ | 6 | $90° < \phi < 180°$ | " " |
| $135° < T < 180°$ | $\sigma > 0$ | 7 | $0 < \phi < 90°$ | $A > 1$ |
| " " | $\sigma < 0$ | 8 | $90° < \phi < 180°$ | " " |

Figure 4

**The above table removes ambiguities arising when the map for I *quadrant* is used; *n is an positive integer; values of $\tau$ such as 30° and 210° are equivalent.**

by inserting (in the most general case) a *four-terminal* network between source and load. This must be such that a *conjugate match* exists between the generator impedance and the *input impedance* to the network. The latter is, in general, different from the load impedance, and may have any value depending on the design of the network. On the other hand, if the network is of *reactive* character (made up of low dissipation elements) the *power input* to the network equals the *power output*. Therefore if we fulfill the condition of maximum power transfer at the *input* of the network, this is also fulfilled at the output and at any intermediate junction. The transmitter delivers all the power of which it is capable and all of this goes into the load. Let us now consider three particular ways of *transforming* a given impedance, by insertion of particularly simple networks.

#### Three Ways of Transforming an Impedance

The coupling network may simply consist of two connecting arms having some value of impedance, which will appear *in series* with the load impedance. Thus we have first, impedance transformation by *addition of a series impedance* (Figure 1(a)). The *transformed impedance* $Z_t$ (impedance *seen* by the generator) is now the *sum* of the original value plus the added series impedance ($Z_t = Z_r + Z_s$).

Another simple network would consist of a shunting arm. Thus we have, in the second case, impedance transformation by *addition of a shunt admittance* (Figure 1(b)). In this case the *transformed admittance* is the sum of the original value and the added shunt admittance ($Y_t = Y_r + Y_p$). It should be noted that the condition of maximum power transfer may be expressed indifferently in terms of *Z* or *Y*. The admittance $Y_t = G_t + jB_t$ must satisfy the following:

$$G_t = G_g$$
$$B_t = -B_g$$

As a third possibility, consider a four-terminal network which is *symmetrical,* in the sense that the input and output terminals may be exchanged without effect on the circuit. In the third case we have impedance transformation by *insertion of a symmetrical network*. This third type of transformation is also subject to a simple law, as we shall see in the following.

#### Three Ways of Identifying a Receiver

A physical receiver (more precisely, a *passive linear two-pole*) is identified electrically by the complex quantity:

$$Z = V/I = R + jX \qquad (1)$$

which we call the impedance (*V* and *I* are the *complex* voltage and current, and their ratio depends only on frequency and on the *parameters* of the receiver).

Another quantity which identifies the receiver is:

$$Y = 1/Z = G + jB \qquad (2)$$

known as the admittance. We have seen how, by using *Y* instead of *Z*, the *impedance transforming action* of a shunting arm may be simply expressed.

The action of a symmetrical network may be expressed just as simply if we identify the receiver by means of a suitable function of Z, namely the function:

$$\rho = \tfrac{1}{2} \ln \frac{Z - Z_o}{Z + Z_o} \qquad (3)$$

where $Z_o$ is the *characteristic impedance* of the network. If $\theta = \alpha + jB$ is the *transfer constant* for the network, the *transformed impedance* (input impedance) is identified by a new value $\rho'$, related to the original value by the equation:

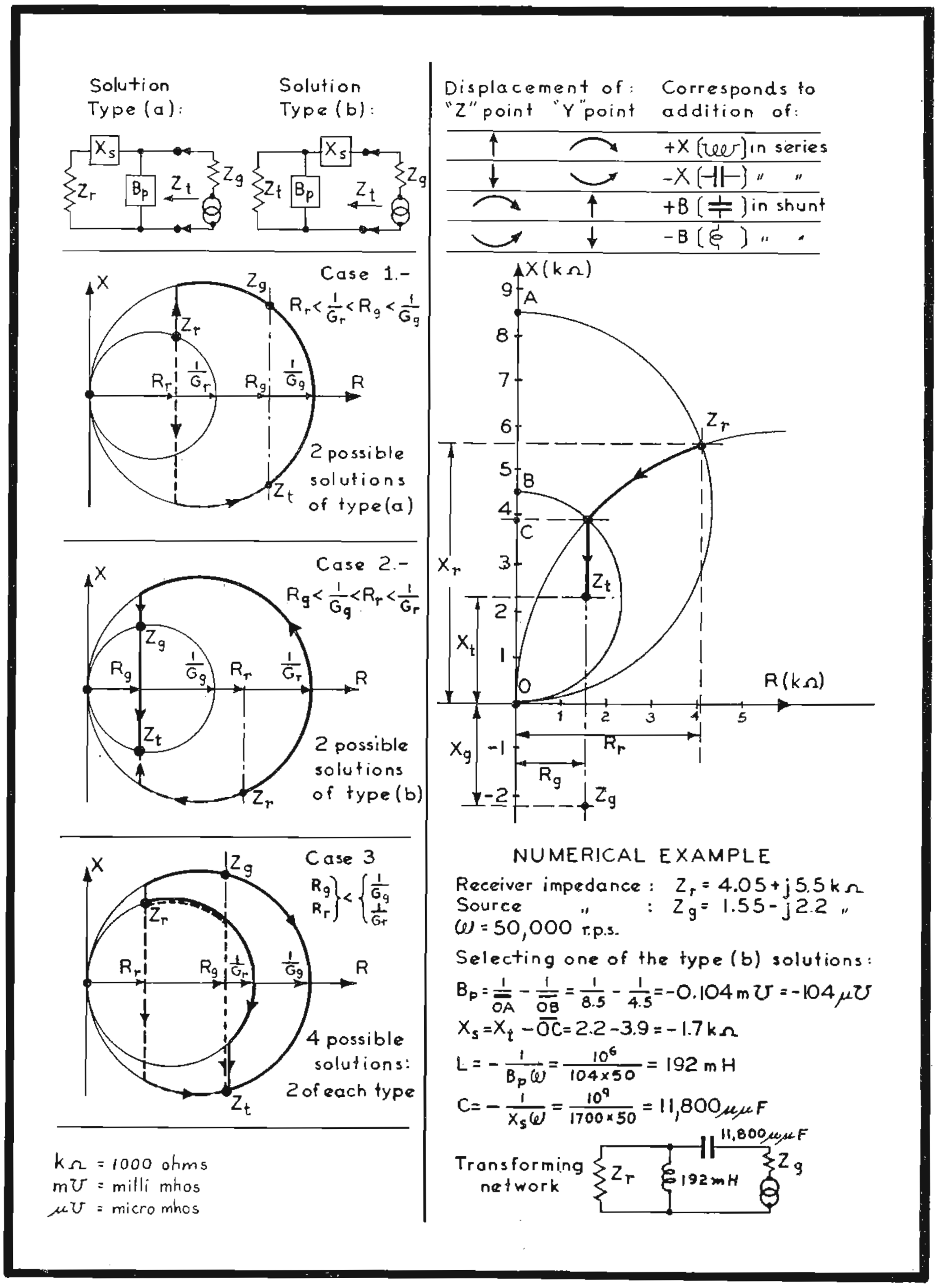
$$\rho' = \rho + \theta \qquad (4)$$

The function $\rho$ may be called *reflection factor*. Like the impedance or the admittance, the reflection factor is a complex number which *describes* the electrical properties of the receiver. An impedance transformation may be expressed in terms of a change in the value of any one of the three complex numbers *Z, Y* or $\rho$. Other functions of *Z* may also be used.

It is always possible to obtain any one of the three quantities Z, Y and $\rho$ when another is known. Thus for example, equation *3* may be used to find

Figure 5

Coupling networks including two reactive branches.




the reflection factor in terms of impedance. Conversely, the impedance in terms of reflection factor is expressed as follows:

$$Z = Z_0 \coth \rho \qquad (5)$$

These expressions, compact as they are, are not very easily computed. Graphical methods serve to overcome this difficulty. Essentially, these methods have the purpose of converting one function of $Z_1$ into another.

### The Complex Plane

Any complex number may be represented by a point on a plane. An impedance:

$$Z = R + jX$$

corresponds to a point on the *Z plane*, of abscissa *R* and ordinate X.

It is easy to find graphically the new value of impedance resulting from the series insertion of a resistance $R_s$ and reactance $X_g$. The *impedance point* simply moves in the positive *R* direction a distance $R_g$, in the positive *X* direction a distance *X* (Figure 1(a)).

The movement of the *Y point* resulting from the addition of a shunt admittance may be traced just as easily (Figure 1(b)).

Supposing, however, two branches were added; one in series, the other in shunt (Figure 1(c)). We would be at a loss in trying to represent an increase in conductance, for example, by the displacement of the *Z* point, whose coordinates are resistance and reactance.

However, we know that on the *Y* plane (of coordinates *G* and *B*) the desired displacement, corresponding to an increase of *G*, is a straight line parallel to the *G* axis. If we knew how such lines *transform* on the *Z* plane the problem would be solved. This *transformation* may be carried out once for all by drawing the *map* of Figure 2 (generally known as *map of the inverse function*), showing lines of *constant G* and *constant B* on the *Z* plane. The identical lines are also loci of *constant R* and *constant X* on the *Y* plane. These lines are circles, and may be easily constructed, as shown in Figure 1, (c) and (d).

The map of the function $\frac{Z}{Z_0} = \coth \rho$ on the ρ plane (also called hyperbolic tangent map) is shown on Figure 3, and in Figure 4. On this map, the impedance transformation due to a symmetrical network is represented by a straight line movement along the ordinates by a distance α equal to the attenuation of the network, followed by a movement along the abscissae over a distance B, phase angle of the network. The map drawn on the plane has the purpose of going from the value of ρ to the corresponding value of *Z* (or *Y*) and vice versa. This map is used mainly in connection with power transmission lines. The map may be used to locate faults in a long cable by impedance measurements.

### Two-Element Couplings

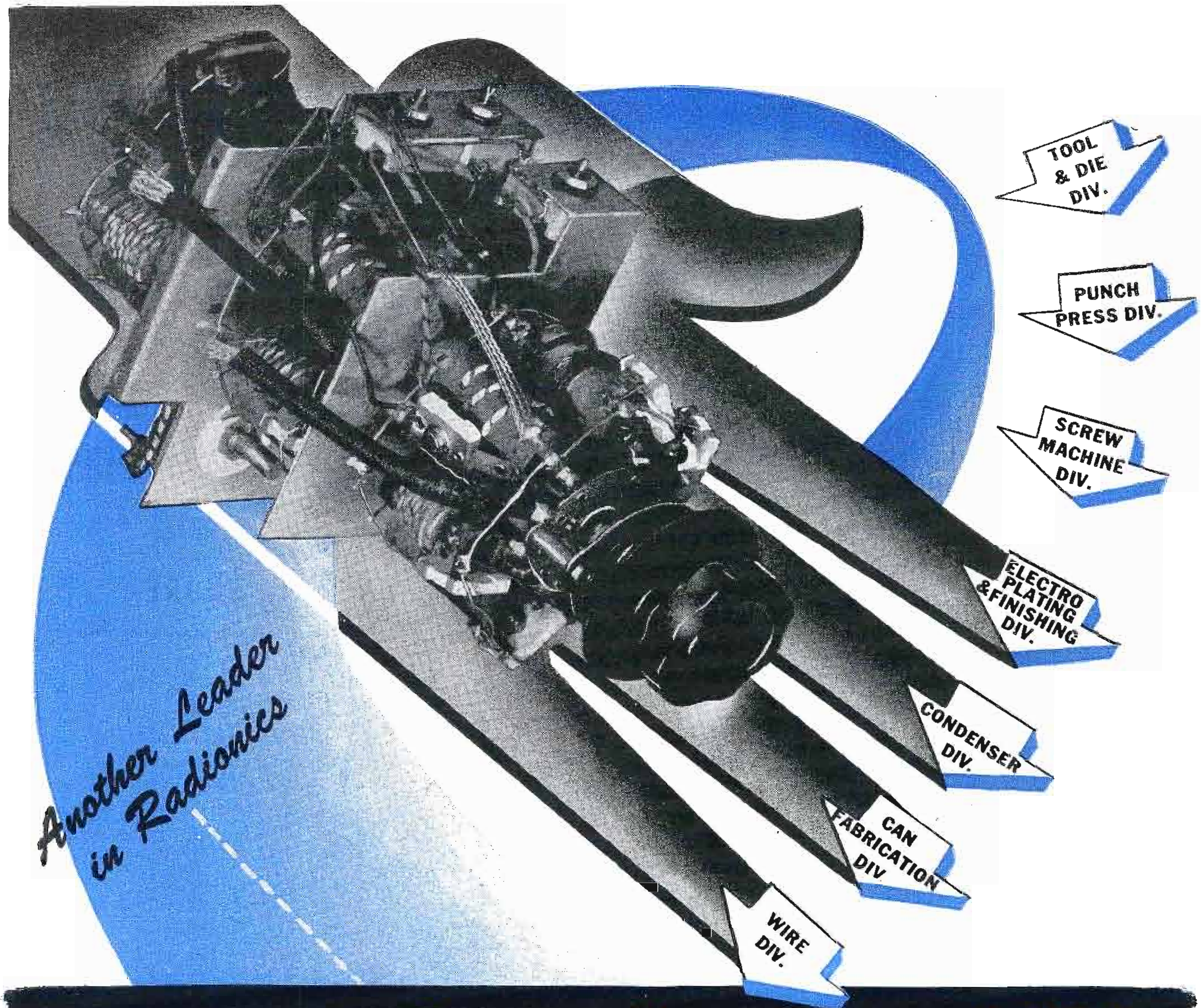
The construction of Figure 1 (c) and (d) may be used to solve, at least *on paper*, any coupling problem as defined in the first section of this article.

This solution calls for two elements: a perfect coil of inductance *L* and a perfect condenser of capacitance C, or, in some cases, two coils or two condensers. The problem is to find the correct values of L or C. A graphical solution appears in Figure 5.

Using, for example, the *Z* plane, we locate, in Figure 5, points $Z_r$ and $Z_g$ (for the load and source impedances which are given); then $Z_t$, transformed impedance, symmetrical to $Z_g$ about the *R* axis (because $Z_t$ and $Z_g$ must be conjugate numbers for maximum power transfer).

We must transform $Z_r$ to the value $Z_t$. Therefore the *Z* point must be brought from $Z_r$ to $Z_t$ in some way. The displacement will be in two steps, corresponding to the addition of a shunt and a series arm in succession (or vice versa). Since only reactive elements may be added (or they would dissipate power), the series arm addition must leave *R*, the receiver resistance, unaltered. Likewise, the shunt arm addition must leave *G* un-

(*Continued on page* 104)

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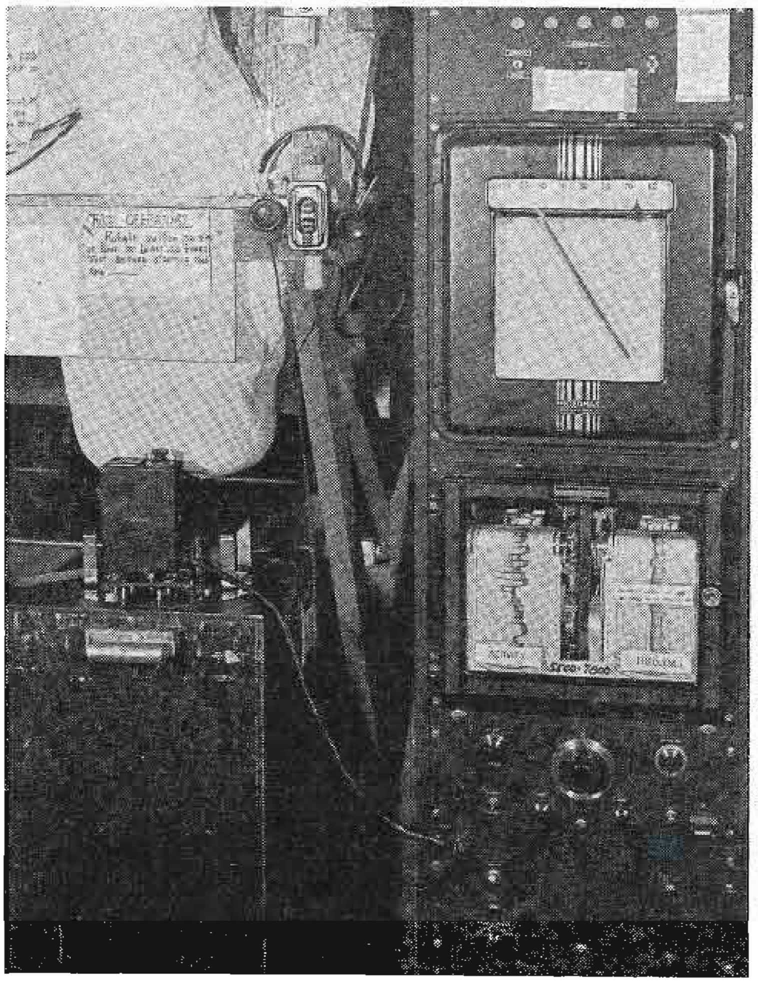
**by SIDNEY X. SHORE**

**Senior Engineer, Crystal Division, North American Philips Company, Inc.**

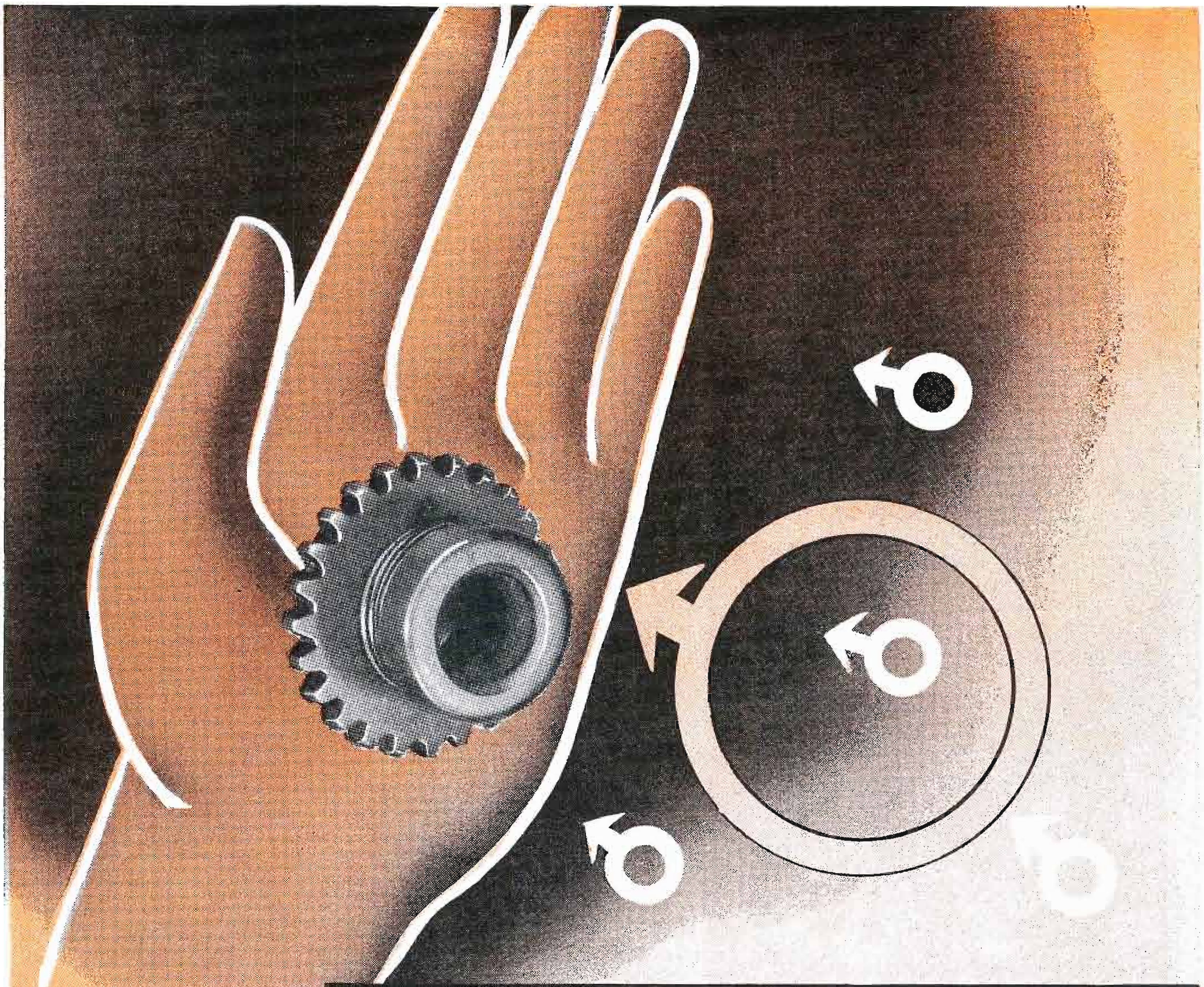
Figures 1 (top, left) and 2 (bottom, left)

Figure 1, a view of the final test equipment for testing frequency deviation and activity of crystals over a temperature range of 145° C. Equipment at top of rack, at right, is the temperature recorder. Activity and frequency deviation recorders are immediately below; direct reading frequency meter is shown in the panel immediately below. At the left is a container with a thermos jug and the switching unit which holds 59 crystals. The test oscillator may be seen resting on the switching unit with its cable leading to the direct reading frequency meter. Figure 2, a section of the electrical maintenance shop where receivers, oscillators, duplicators, final test equipment and all other electrical equipment are maintained in perfect operating order.

A FINISHING technique should consider the effects of aging upon frequency and activity of the finished product. As mentioned earlier, cleaning up the surface of abraded quartz seems to materially lessen the aging effect. Various techniques have been utilized in an attempt to either eliminate or accelerate the aging period so that when a crystal is shipped from the manufacturer, the frequency marking will be just as accurate six months or a year or ten years from the date of shipment.

A common treatment designed to reduce the effects of aging is a series of hot and cold cycles. This may result simply in a breakdown of the comparatively coarse surface structure left by the abrasion of the final lapping compound into a finer structure by the chipping and cracking of the microscopic hills and cliffs on the surface. If the crystal is thoroughly cleaned after this heat treatment, aging is markedly inhibited.

Electrodes which clamp the crystal at the four corners and which provide for a gap between the surface of the oscillator crystal and the electrodes are in common usage today. A comparatively new type of electrode that is being developed at present, and should find itself utilized more and more as its properties are discovered, is the plated electrode. Metals such as gold, silver or aluminum are used as surface coatings for the crystal oscillator plate, with spring wire terminals sweated on to the metal surface. Techniques for coating crystals and for ap-



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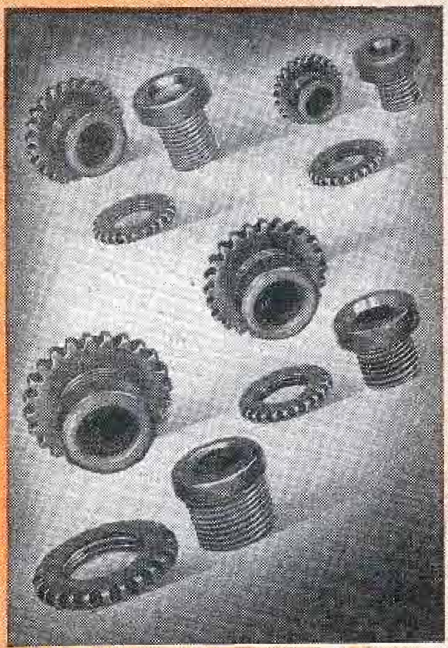

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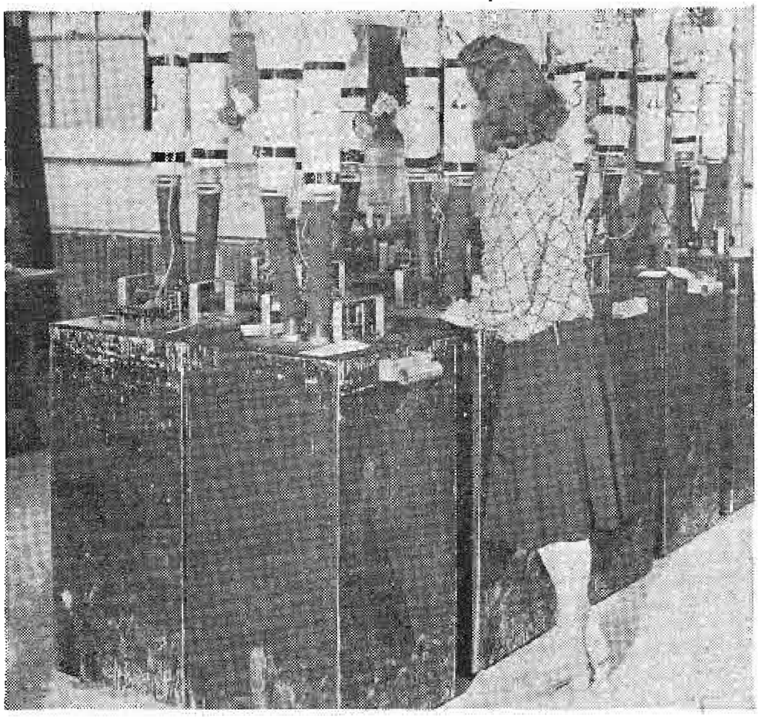

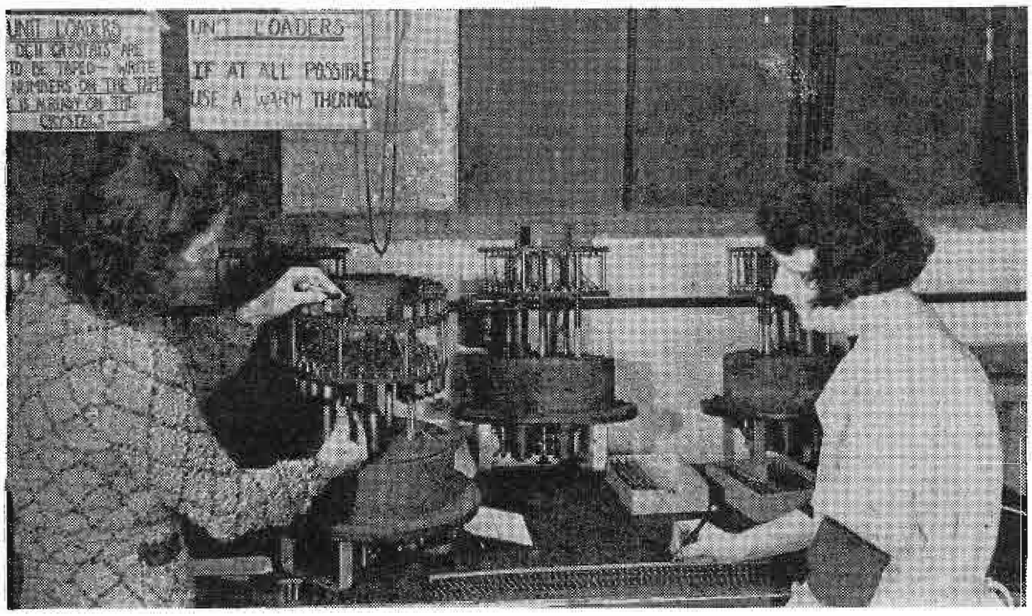


Figures 3 (left) and 4 (below)

In figure 3, a view of 10 switching units being heated to 90° C. Thermocouples and a recording potentiometer-temperature device are used to measure temperature within the thermos jug. Figure 4 shows a switching unit being loaded with 59 crystals. The 60th position is occupied by a crystal holder containing a *copper-constantan* thermocouple. The crystals are numbered and rejected crystals may thereby be easily identified when the heat run is completed.

plying the terminal wires are improving rapidly and there seem to be many benefits accruing from their use. In view of the intimate relationship between electrode and crystal, there is no measurable air gap. Thus the series reactance normally introduced by the air gap is at a minimum. Therefore, we may expect that the activity will be greater.

Gold plate is very conveniently applied in the sputtering process. It is non-corrosive and heavy. Because of its mass, it is possible to utilize an etching technique to stabilize the abraded surface of the oscillator plate. Then its frequency can be raised as much as 50 or 75 kilocycles above the desired nominal frequency by the plating. The loading effect of the heavy gold plate may be controlled merely by the thickness of the gold sputtered on to the surface of the oscillator plate. This loading effectively decreases the resonant frequency of the crystal and a vernier frequency control system may be thus derived. Another possible effect of plated electrodes is a decrease in surface friction, especially for thickness-shear oscillator plates. This decrease in surface friction may be the result of lubrication of the surface by the gold and may explain some of the increased activity noticeable with plated crystals. If an excessive amount of gold, or any of the other commonly used metals is applied so that the frequency is too low, an appropriate solvent may be utilized to remove some of the plating and thereby restore the frequency to the desired value.

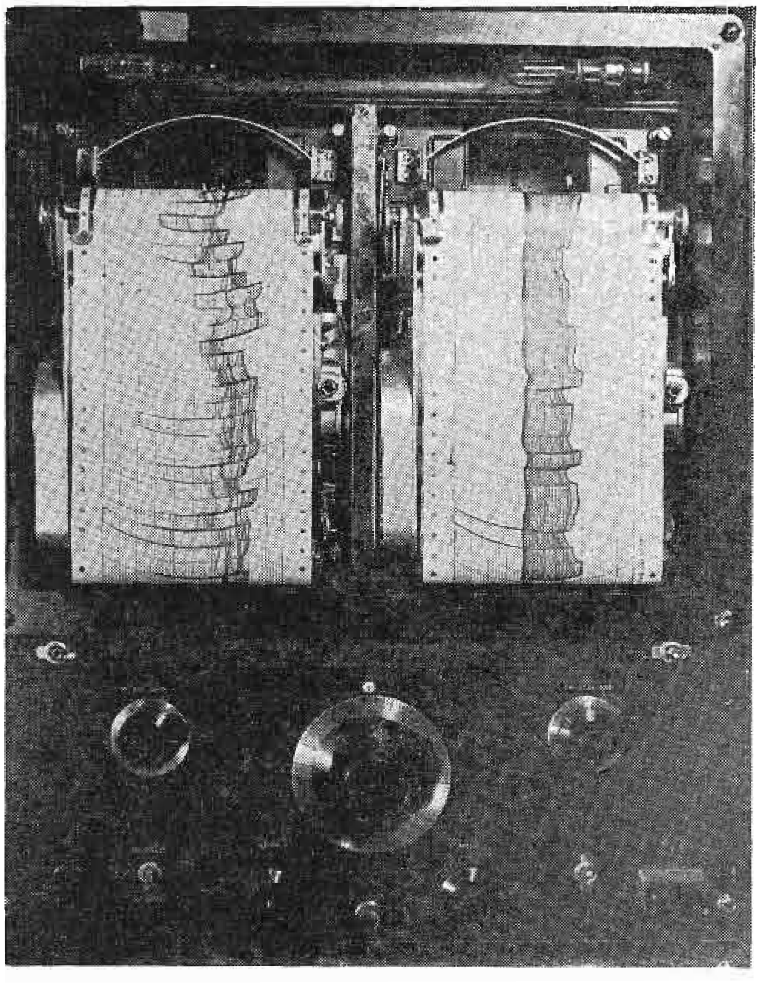

Figure 5

A closeup of the Esterline-Angus activity and frequency deviation recorder. The chart at the left records the activity of each crystal at two minute intervals, while the chart at the right records frequency deviation from nominal at the same intervals. Each crystal is represented by a group of lines drawn once every two minutes. Temperature is changed at the rate of 1° per minute over the entire range. The direct reading frequency meter with its various controls and reference standard crystal is shown in the panel immediately below the recorders.

Owing to the diverse nature of the temperatures and the climates where crystal oscillator plates may be used, each crystal is subjected to a test procedure which will determine its frequency and activity stability at the extreme high and low temperatures in addition to the entire range of temperatures between the extremes. A minimum activity requirement is set and any crystal whose activity drops below this minimum at any point throughout the temperature range is rejected.

If a crystal is cut at an improper angle, its frequency deviation may exceed the narrow tolerance for proper functioning in transmitters and receivers. An examination of the chart showing the variation of frequency with temperature change will illustrate that the angle of cut should be such that the turning point temperature will occur at the middle of the test temperature range. This will utilize the symmetry of the temperature coefficient curve to its best advantage.

If the operating conditions of a crys-


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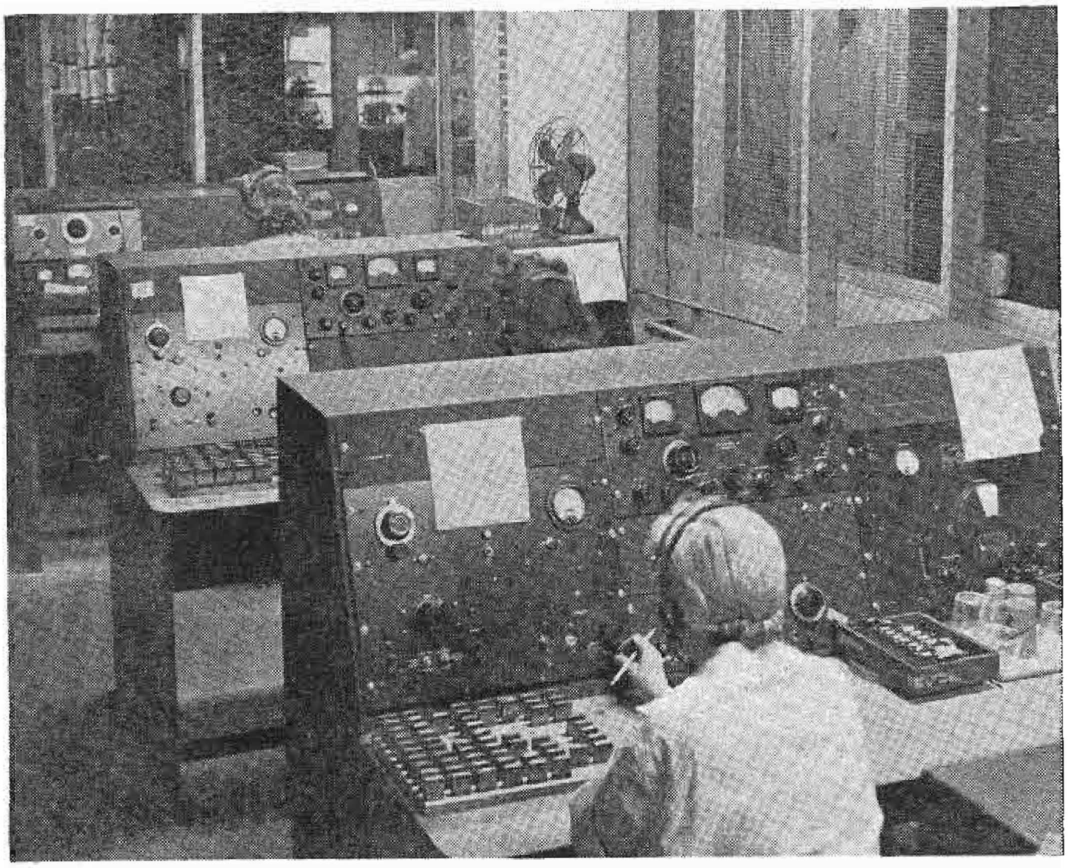
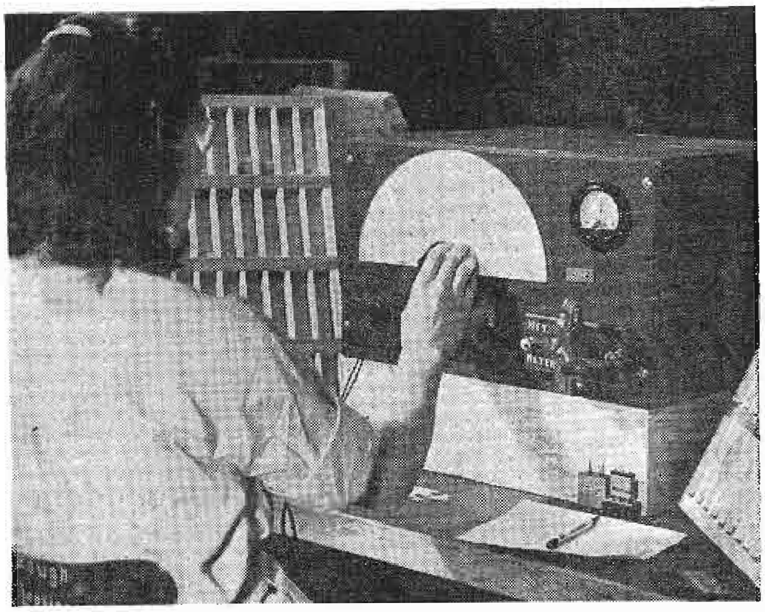
Figures 6 (right) and 7 (right, center)

Figure 6, calibrating console positions where exact frequencies of standards are measured and adjusted. The standard reference frequency is obtained from a General Radio primary standard checked daily against WWV. Standard crystals are cut at such an angle that the turning point occurs at the operating temperature which may be several degrees above room temperature. Figure 7 shows a heterodyne frequency meter and activity checker used for channeling crystals into narrow frequency bands. The scale indicates the frequency to which a stable electron-coupled oscillator is tuned. This oscillator beats with the crystal oscillating in the test oscillator. The frequency of the e-c-o is adjusted until zero beat is detected in the head phones. The frequency of the crystal is then recorded directly on the scale. Two calibrating crystals are shown on the table just below the frequency meter.





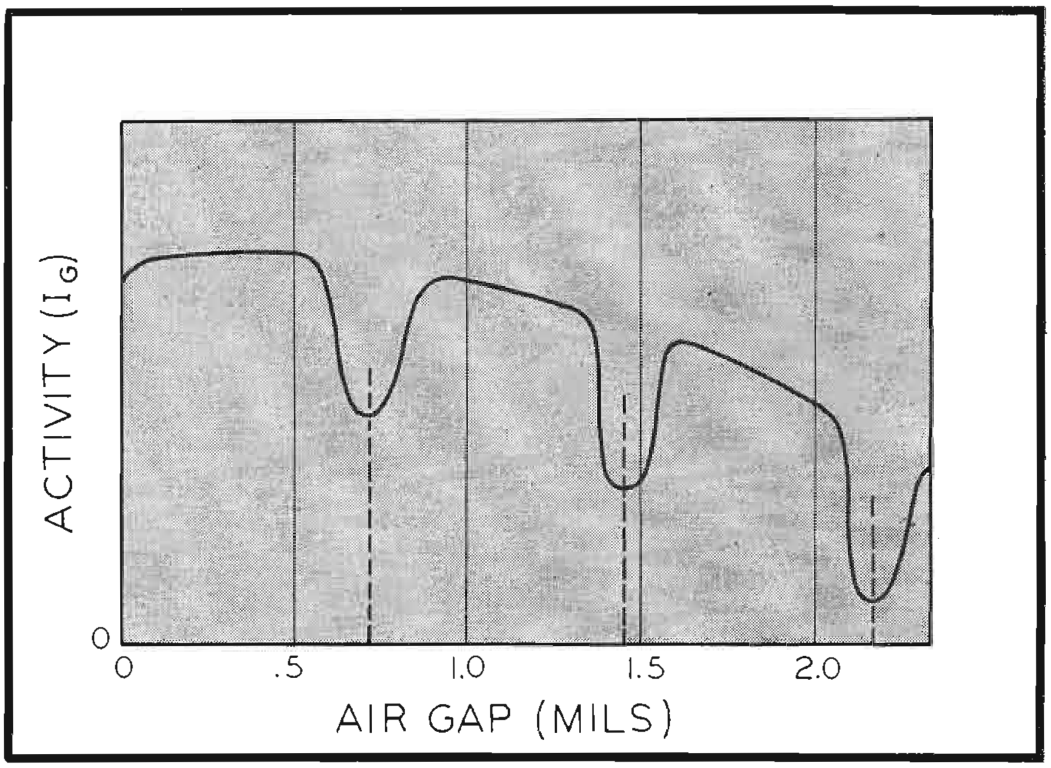
tal in an aircraft were considered, we would see that from the time of take-off to the time of maximum altitude, and then to the time of return to earth, the crystal would encounter varying conditions of temperature, humidity, and atmospheric pressure. In the stratosphere, temperatures up to 112° C below zero have been recorded above Miami, Florida. In the troposphere, the temperature has been measured at 70° C to 80° C below zero. A usable crystal must function at these various temperatures and also at the high temperatures in the bulkhead when the plane is warming up on the ground in equatorial locations.

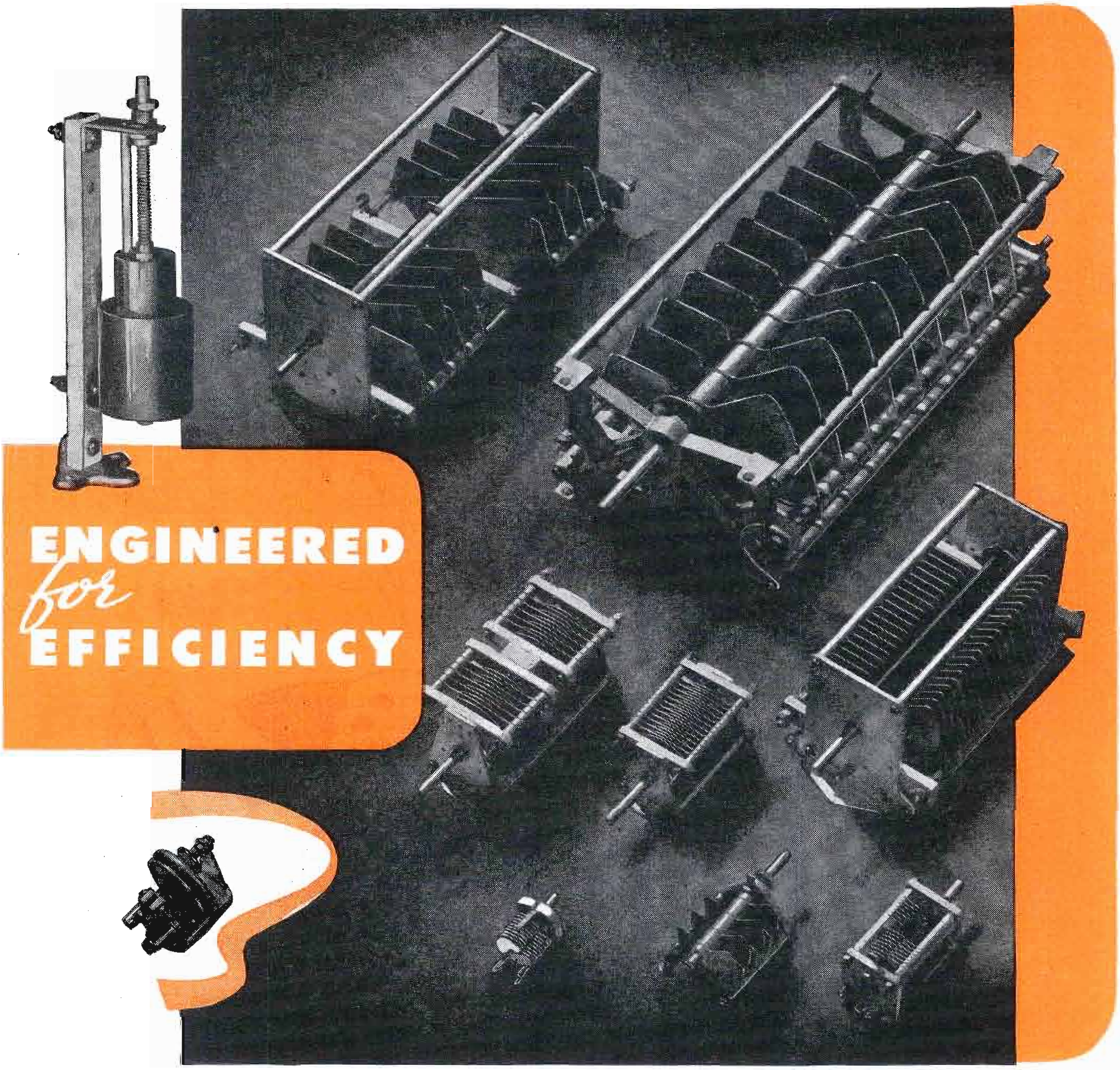
If the crystal holder has an air leak the internal air pressure will decrease as the plane ascends. In a dive the atmospheric pressure increases and the air will leak into the holder again. But if the plane dives through cloud formations where the relative humidity is high a great deal of moisture may accompany the air returning into the holder through the leak. It is likely that the crystal may be short-circuited thus and become inoperative. To avoid this dangerous possibility every crystal holder, complete with crystal, must be subjected to an altitude test. In this test, the holders are placed in an enclosed volume which is evacuated. A high d-c voltage is applied to the electrodes. If no leak of air from the holder into the evacuated volume occurs no appreciable current will flow across the electrodes. If a leak is present, a discharge current may be observed with a series microammeter. This condition will appear as the air pressure inside the holder drops to a value which will permit of ionization and current flow.

Contact pins of crystal units must

Figure 8 (below)

Diagram illustrating air gap resonance effects on activity of a crystal. Thickness-shear oscillators are much less affected than pure thickness oscillators.



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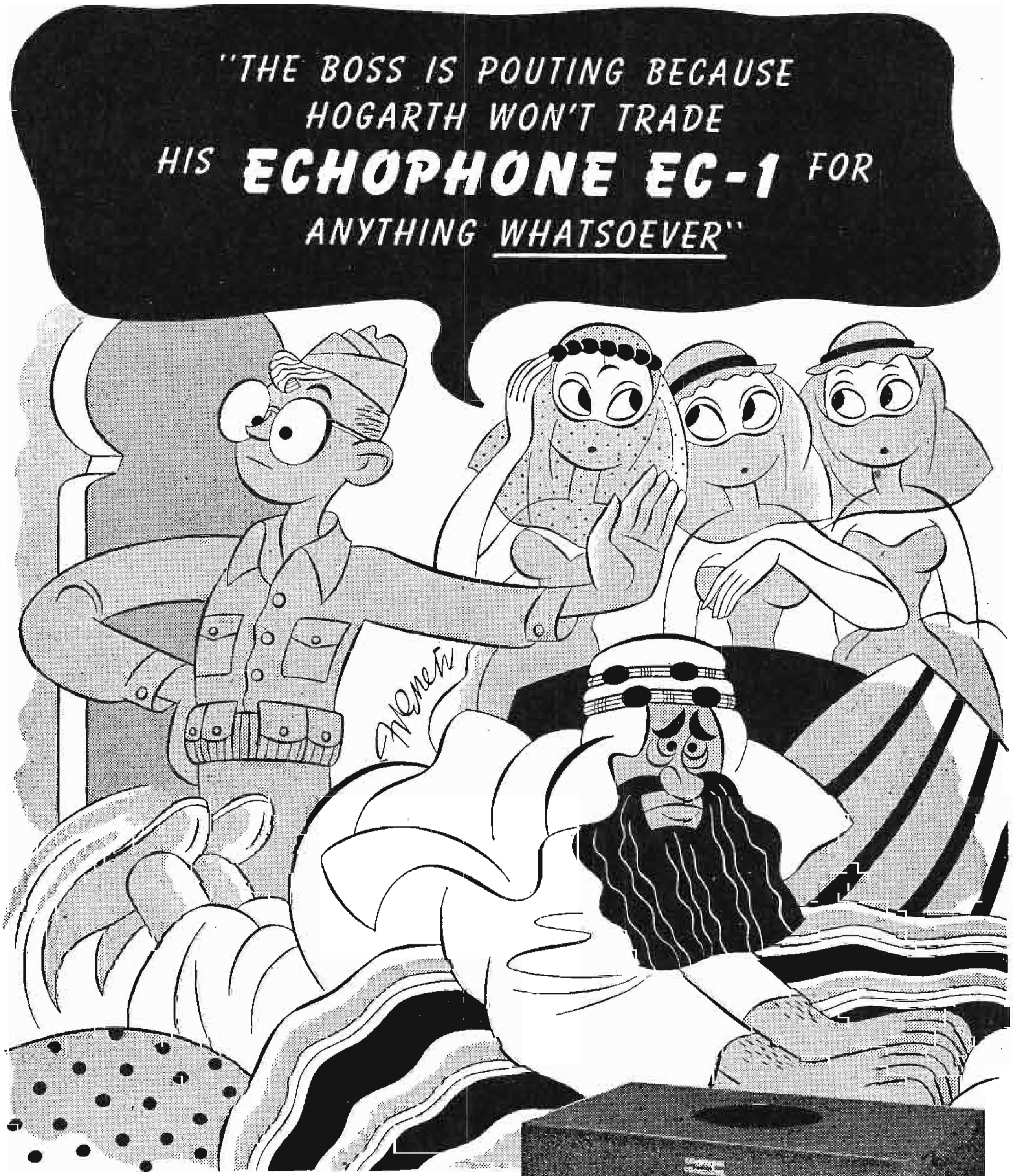


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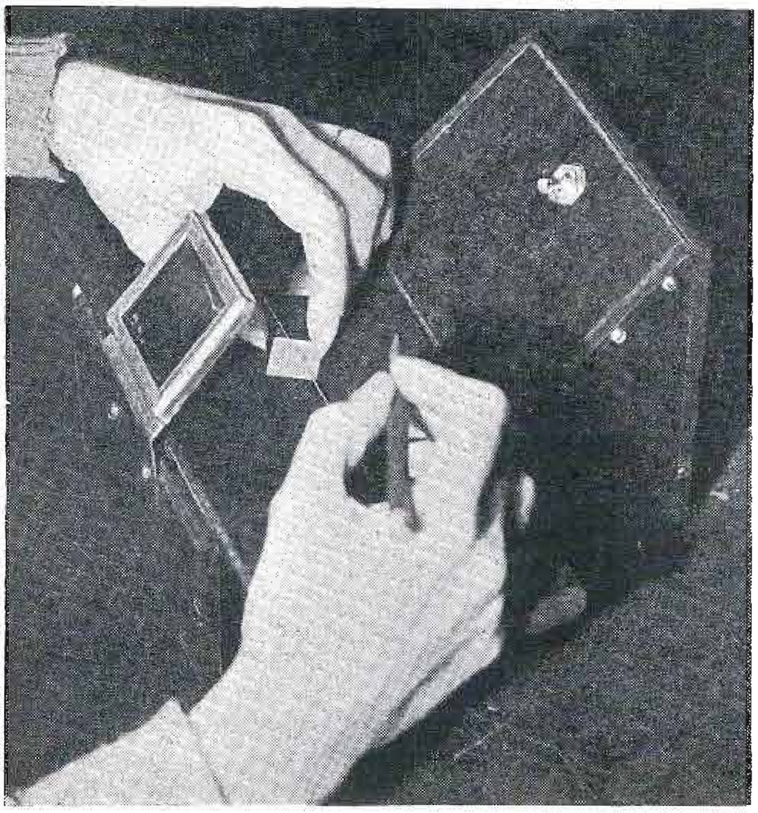

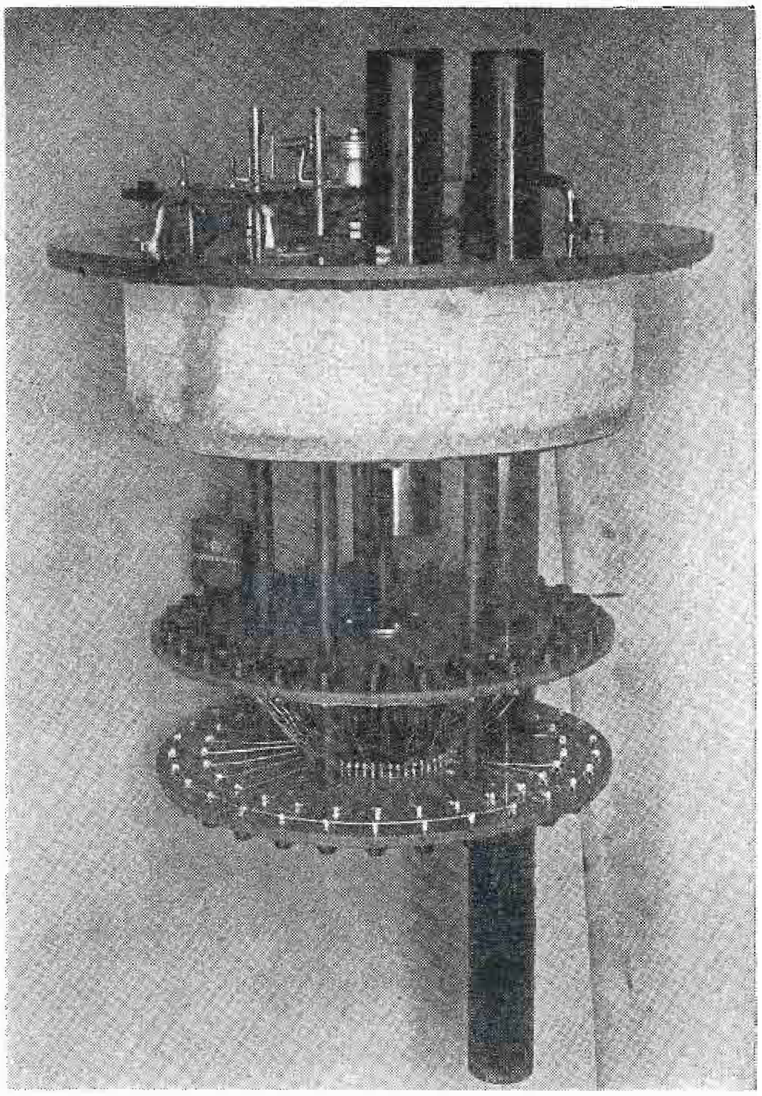

Figures 9 (top) and 10 (right)

Figure 9, a stauroscope used to locate and differentiate the X and Z'-axis in a wafer or a blank. This facilitates the accurate x-ray measurements of the ZZ' and the XX' angles. In Figure 10, we see a view of the switching unit used in the heat cycle activity and frequency test. There are 59 sockets which hold 59 crystals. These are connected to switch points and a wiper arm sweeps over the switch points making contact with each in turn. The complete cycle occurs every two minutes.

be of material that will not corrode particularly when the crystal is to be used for sea duty, where constant salt water atmosphere prevails. Nickel-plated brass is used almost exclusively. Other low resistance non-corrosive metals and alloys are being contemplated as substitutes. Platings sometimes scratch or peel and expose the tarnishable metal underneath. Nickel plate in particular forms a tough and a very high resistance oxide layer which may on occasion cause contact trouble.

If a crystal were to be used in equatorial climates where the average temperature is high, a desirable ZZ' angle may be 49° or lower. For arctic climates, the ZZ' angle may well be 49° 50' or higher. It must be remembered that at only one point, the turning point, is the temperature coefficient of frequency equal to zero. At temperatures below the turning point, the temperature coefficient of frequency is positive and at temperatures above the turning point, the temperature coefficient of frequency is negative.

A continuous measure of activity and frequency of the crystal while the crystal is carried through the entire temperature range results in a somewhat lengthy hot and cold test procedure. A more common system of temperature testing makes checks of activity and frequency of each of a series of 50 or 60 crystals in turn at one or two-minute intervals. With a synchronized recording chart, activity and frequency may be recorded periodically at these intervals and barring an exceedingly sharp activity dip, the recordings will be quite accurate. One type of such intermittent recording device is shown in Figures 1 and 5.

The major reject causes are activity dips at certain temperatures. These

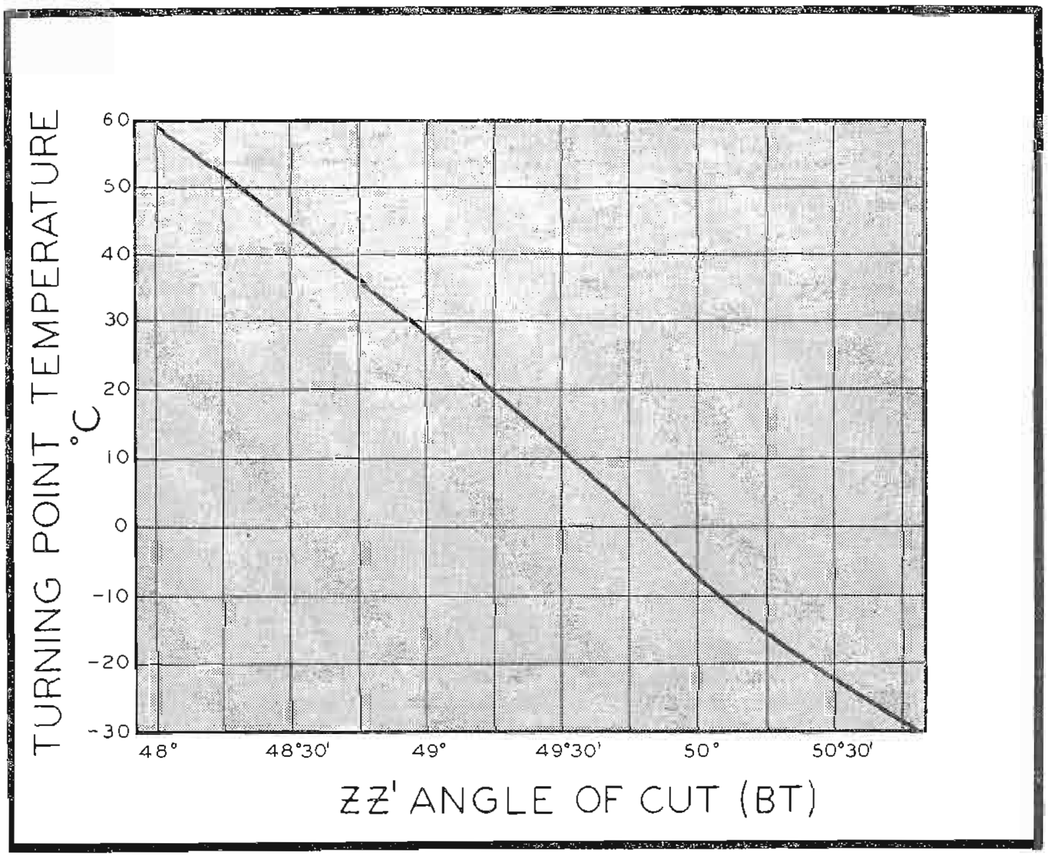


Figure 11

Chart shows values of turning point of the *BT*-temperature coefficient curve as a function of the ZZ'-angle of cut. XX' is assumed to be 0°. This represents a statistical average of many turning points as run in the laboratory. Any tilt of the blank with respect to the X-axis will lower the temperature of turning point; frequency of oscillator plate and nature of the surface are other factors.

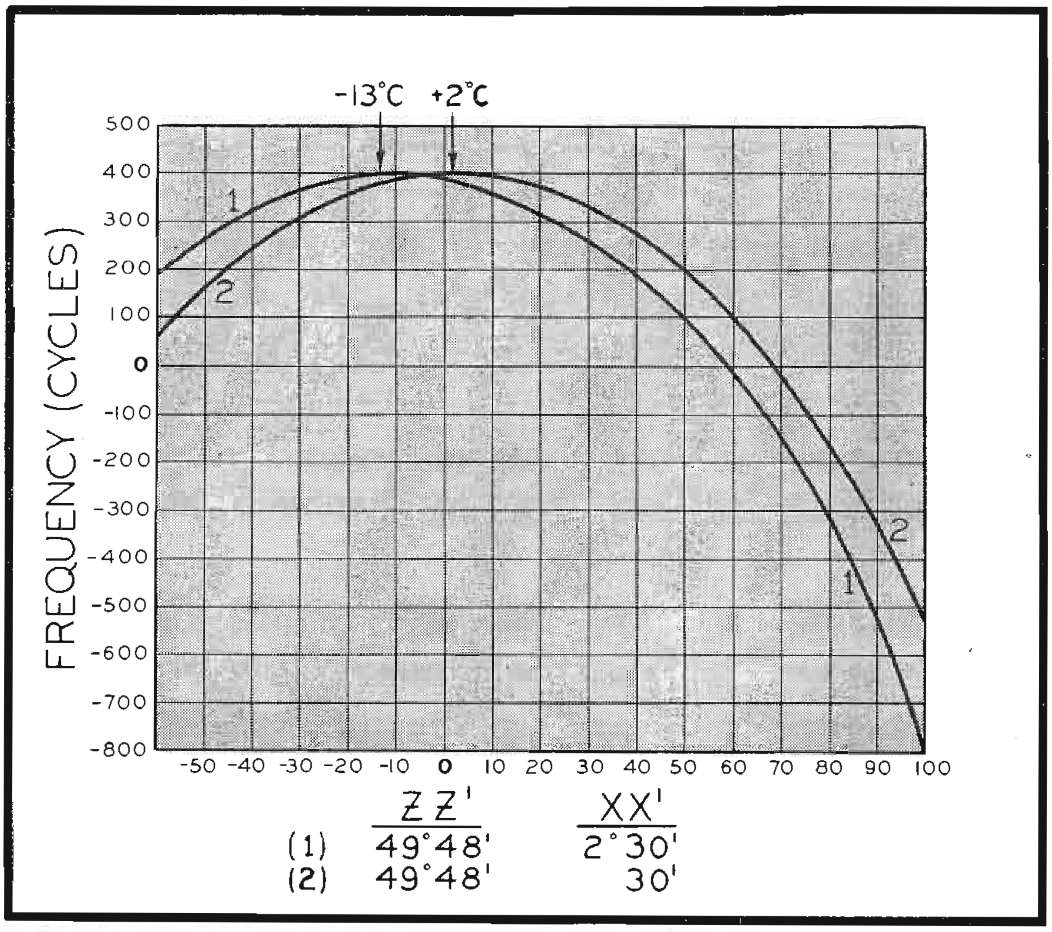


Figure 12

Figure 12, chart shows the effect of an alteration of *XX'*-angle upon the *turning point* temperature.

dips are the result of interfering modes of vibration whose harmonics couple destructively with the fundamental thickness-shear mode, and also may be caused by improper mechanical conditions of the electrodes or the spring. An analysis of reject causes generally shows that activity dips occuring over a small temperature interval are the result of improper dimensioning causing the above mentioned interfering coupling. Poor mechanical assemblies generally show up as gradual activity dips over a long temperature range. To correct dips caused by improper dimensioning the edges are reground so as to change dimensions, thereby eliminating the interfering coupled modes over the required temperature range.

A precise study of dimensions would allow for a predimensioning technique to be utilized with great success. Precision edge-grinding equipment would be necessary to hold face dimensional tolerances to within .0001".

An interesting phenomenon which occurs especially with straight thickness oscillators is the air-gap resonance effect. If there is any component motion of the crystal surfaces in the direction of the electrodes, a supersonic air pulse will be set up at the frequency of oscillation of the crystal. This air pulse will traverse the air gap and be reflected by the electrode back towards the crystal. If the total path traveled by the air pulse is equal to the wave-length of the supersonic wave, destructive interference will occur when the pulse returns to the

(*Continued on page* 96)

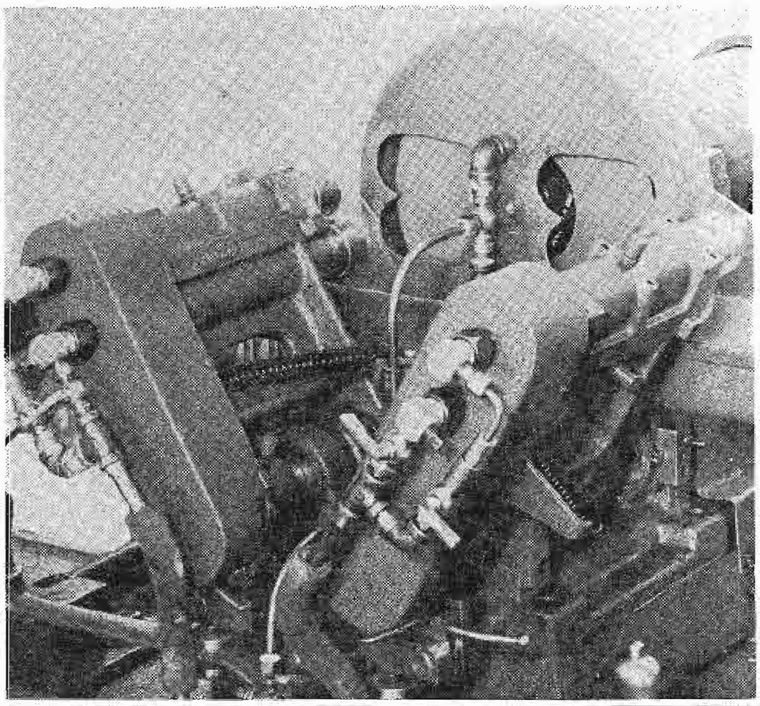

Figure 13

Q-lap developed by Theodore Schaffers, chief mechanical engineer of the North American Philips crystal division. This lap uses a diamond wheel for quickly reducing the thickness of rough-cut blanks. Mechanical tolerances for this lapping machine are kept as close as .0001".

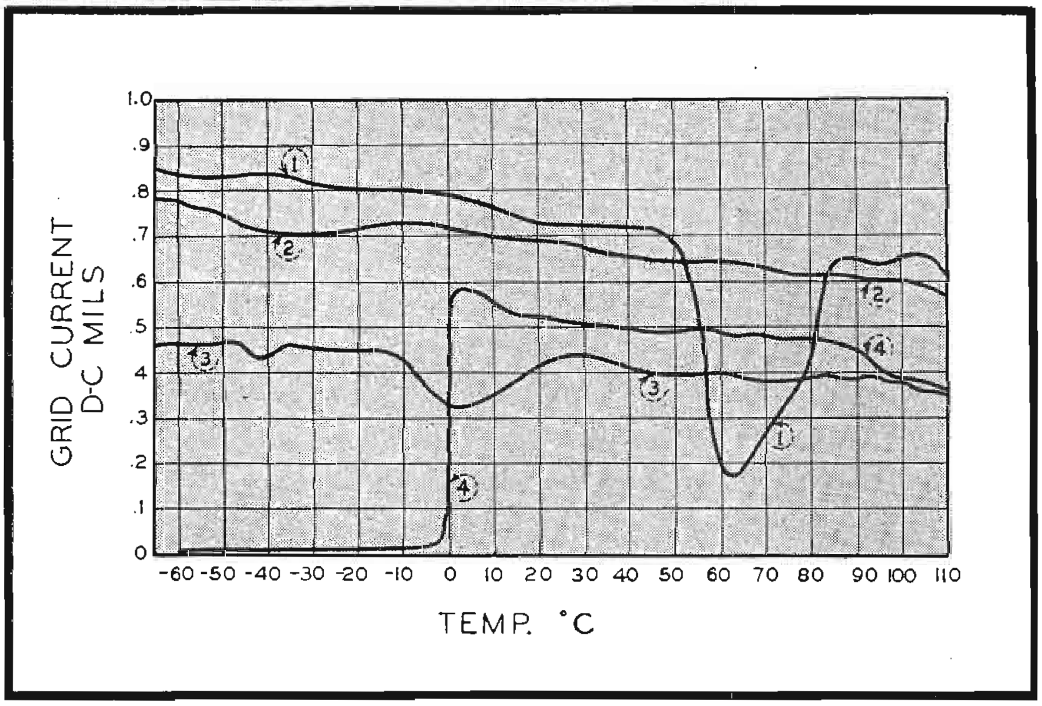


Figure 14

In *1*, we have an activity temperature curve of a rejected crystal, showing the sharp activity dip with its minimum at 62° C. In *2*, we have the same crystal, its face dimensions decreased slightly, showing slightly lower activity overall, but having stable characteristics. Curve *3* shows another crystal having no severe dips but with generally lower activity. Note the slight dips which may result from relaxation or slippage of the crystal spring holding the electrodes fast against the crystal. Physical behavior of a crystal in a holder which has moisture in it, as the crystal and holder are cooled from + 110° C. to — 60° C. is shown in curve *4*. Note that at the freezing point of water, the vapor precipitates out and apparently completely damps vibration of the oscillator plate. There is a general increase in activity as the temperature of the crystal is lowered. One reason may be the decreased pressure within the holder offering less damping effect to the crystal vibration.

# WHEATSTONE BRIDGE APPLICATIONS

A portable Wheatstone bridge with Murray and Varley loop circuits and additional multiplier steps on the ratio dial for the Murray loop.

*(Courtesy Industrial Instruments, Inc.)*

## An Analysis of Methods Used in Location of Faults in Lines, Loops and Cables

**(PART TWO OF A THREE-PART PAPER)**

**by PAUL B. WRIGHT**

**Communications Research Engineer**

**Part 1 of this paper analyzed some of the more general aspects of the requirements of the component parts of the Wheatstone bridge. The accuracy and sensitivity conditions were investigated and the necessary relationships between the parameters of the bridge network were shown. The usage of shunts for the protection of the galvanometers used in the bridge circuit was also discussed. Types of conductors and the fundamental equations relating to their resistance at different temperatures were considered. In this installment some of the theoretical and practical conditions of operation of the bridge for line fault location work are reviewed.**

FOR copper wire of approximately 98 per cent of the conductivity of annealed copper, in the practical system of English units and degrees Fahrenheit, equation *21* of Part 1 becomes.

$$\frac{R_1}{R_2} = \frac{395 + t_1}{395 + t_2} \qquad (21b)$$

where $R_1$ = temperature at $t_1$ degrees Fahrenheit, $R_2$ = temperature at $t_2$ degrees Fahrenheit. For example, if the resistance of a 165-gauge pair of copper wires is known to be 4.12 ohms per loop mile at 70° F, then the resistance at some other temperature, say 100° F, by equation *21b* is equal to 4.38 ohms per loop mile. Again if the resistance of a 16 B & S gauge cable pair of copper wire is known to be 46.0 ohms at 110° F, the resistance by *21b* at 50° F would become 40.6 ohms. Tables one to four give the resistance of a number of different

**Table 1**

*Open Wire Circuits*

**Hard Drawn Copper**

| *No.* | *Gauge* | *Dia. in inches* | *Ohms per loop mile* |
|---|---|---|---|
| 4.... | AWG | .204 | 2.72 |
| 6.... | AWG | .162 | 4.33 |
| 7.... | AWG | .144 | 5.46 |
| 8.... | BWG | .165 | 4.10 |
| 9.... | AWG | .114 | 8.68 |
| 10.... | NBSG | .128 | 6.82 |
| 10.... | AWG | .102 | 10.55 |
| 12.... | NBSG | .104 | 10.3 |
| 14.... | NBSG | .081 | 17.4 |

**Table 2**

*Open Wire Circuits*

**Copper Weld**

| *No.* | *Gauge* | *Dia. in inches* | *Ohms per loop mile* 40% | 30% |
|---|---|---|---|---|
| 4.... | AWG | .204 | 6.74 | 8.98 |
| 5.... | AWG | .182 | 8.51 | 11.35 |
| 6.... | AWG | .162 | 10.72 | 14.32 |
| 7.... | AWG | .144 | 13.53 | 18.05 |
| 8.... | AWG | .128 | 17.09 | 22.72 |
| 9.... | AWG | .114 | 21.54 | 28.66 |
| 10.... | AWG | .102 | 27.16 | 36.16 |
| 11.... | AWG | .091 | 34.21 | 45.60 |
| 12.... | AWG | .081 | 43.20 | 57.50 |
| 13.... | AWG | .072 | 54.45 | 72.60 |
| 14.... | AWG | .064 | 68.60 | 91.50 |

**Table 3**

*Open Wire Circuits*

**BB Galvanized Iron**

| *No.* | *Gauge* | *Dia. in inches* | *Ohms per loop mile* |
|---|---|---|---|
| 4.... | BWG | .238 | 14.22 |
| 6.... | BWG | .203 | 19.62 |
| 8.... | BWG | .165 | 29.76 |
| 9.... | BWG | .148 | 36.92 |
| 10.... | BWG | .134 | 44.90 |
| 12.... | BWG | .109 | 68.15 |
| 14.... | BWG | .083 | 117.1 |

**Table 4**

*Cable Wire Circuits*

**Hard Drawn Copper**

| *No.* | *Gauge* | *Dia. in inches* | *Ohms per loop mile* |
|---|---|---|---|
| 10.... | AWG | .102 | 10.7 |
| 13.... | AWG | .072 | 21.4 |
| 16.... | AWG | .051 | 42.2 |
| 19.... | AWG | .036 | 85.0 |
| 22.... | AWG | .025 | 171 |
| 24.... | AWG | .020 | 274 |
| 26.... | AWG | .015 | 440 |

[All resistances given are at 20°C or 68°F]


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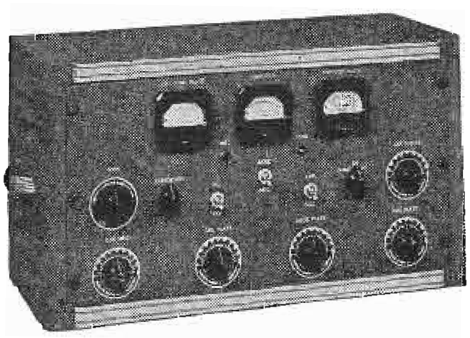

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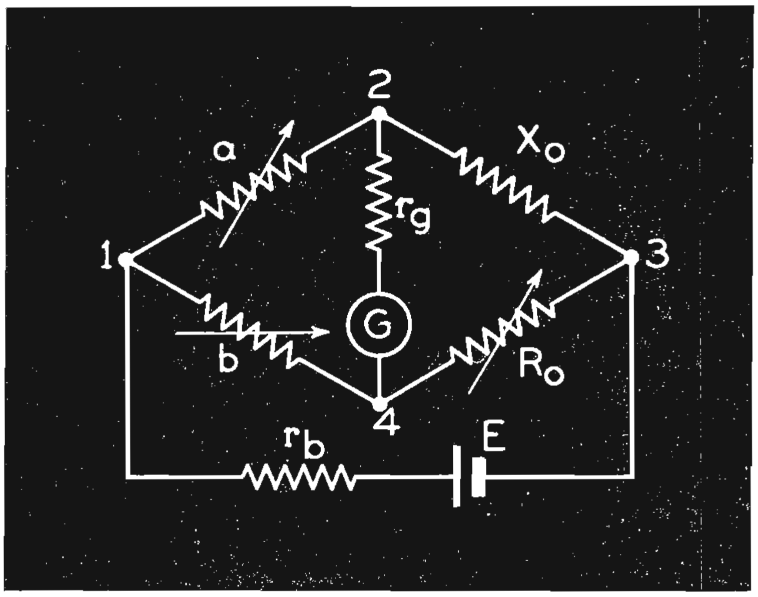
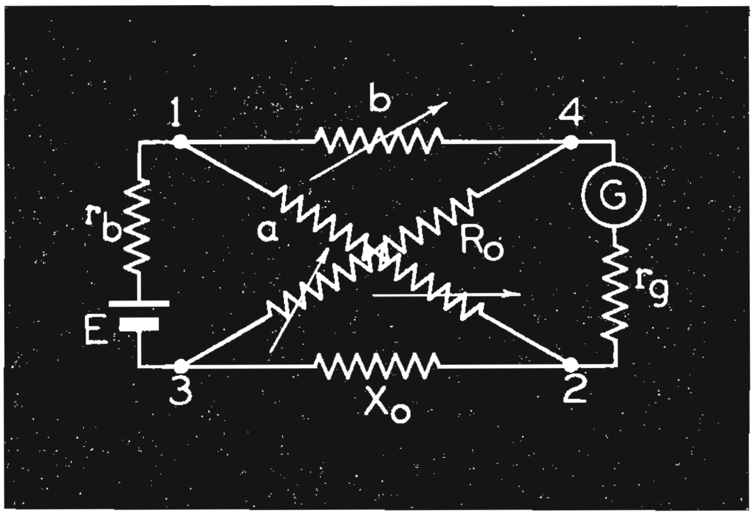



Figures 3 (left) and 4 (top)
Figure 3, a conventional schematic of the Wheatstone bridge circuit. Figure 4, a lattice view of the same network shown in Figure 3.

types of conductors used in open wire and cable communication systems.

**Theory of The Bridge**

***Condition . . . measurement of a simple resistance $X_o$.*** At balance (Figure 3), the galvanometer current $i_g=0$ and the potentials across resistances *a* and *b* are equal; likewise those across $X_o$ and $R_o$ are equal. Therefore we may write the equilibrium equations

$$i_{2,3}X_o = i_{3,4}R_o \qquad (23)$$

and

$$i_{1,2}a = i_{1,4}b \qquad (24)$$

dividing these member by member, and noting that $i_{1,2}=i_{2,3}$ and $i_{3,4}=i_{1,4}$, we get

$$\frac{X_o}{a} = \frac{R_o}{b} \qquad (25)$$

or the unknown resistance,

$$X_o = R_o \frac{a}{b} \text{ ohms} \qquad (26)$$

which for $a = b$ becomes

$$X_o = R_o \text{ ohms} \qquad (27)$$

These equations are the fundamental equations of the Wheatstone *d-c* bridge, and are also the equations for all of the special *a-c* bridges in which the resistances are replaced by reactances or combinations of them.

**Loop Measurements**

Figure 6 shows a loop of *l* ohms per wire. Letting the total loop resistance $L=2l$, this is the same as the case of the simple resistance. Therefore, dropping subscripts, we can write immediately, for $a > b$ or $a < b$

$$L = R\frac{a}{b} \text{ ohms} \qquad (28)$$

and when $a = b$,

$$L = R \text{ ohms} \qquad (29)$$

**Grounded Varley**

***Condition . . . fault of x ohms from far end of line (Figure 7).*** Short far end, and connect as shown, first as in Figure 6 for loop, and Figure 7 for Varley measurement.

*Method one:* with equal ratio arms, or $a = b$.

$$\text{Here } R_o = R + d = l + x \qquad (30)$$

$$\text{or} \quad d = (l + x) - R \qquad (31)$$

The loop resistance

$$L = l + x + d \qquad (32)$$

$$\text{or} \quad d = L - (l + x) \qquad (33)$$

adding 31 and 33

$$2d = L - R = L - V \qquad (34)$$

This is the loop resistance distance from the measuring end. V is called the Varley measurement. It is the value of *R* when the bridge is connected for a Varley test. The distance to the trouble is found by considering the fraction of the total obtained for the difference of *L* and *V*. The percentage of the total distance is

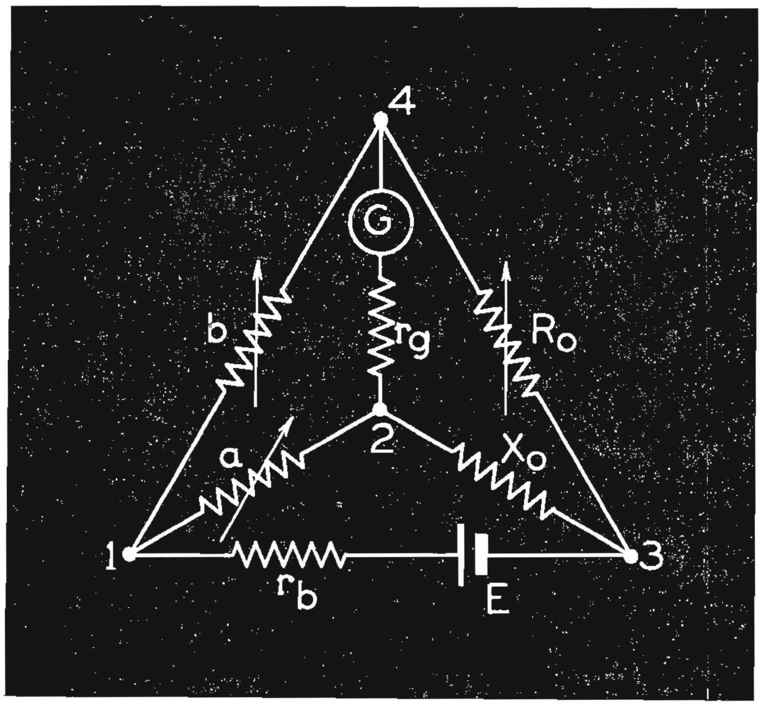
$$100.\frac{L - V}{L} \text{ per cent} \qquad (35)$$

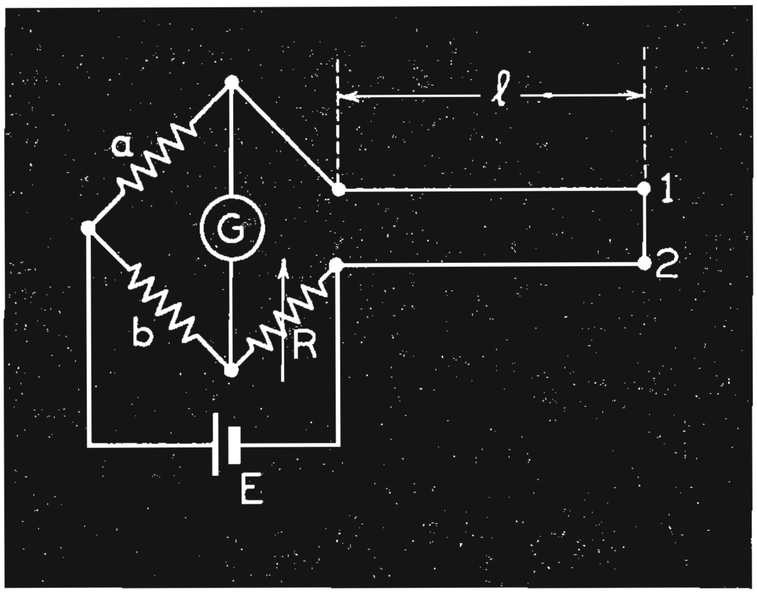
and the actual distance is

$$D \cdot \frac{L - V}{L} \text{ miles} \qquad (36)$$

If the distance is not known, the quotient of the loop minus the Varley and the resistance per loop mile (corrected for temperature) will give the distance to the fault.

Figures 5 (left) and 6 (below)
Figure 5, the star-delta formation of the bridge of Figures 3 and 4. Figure 6, a simple loop measurement of a pair of wires.

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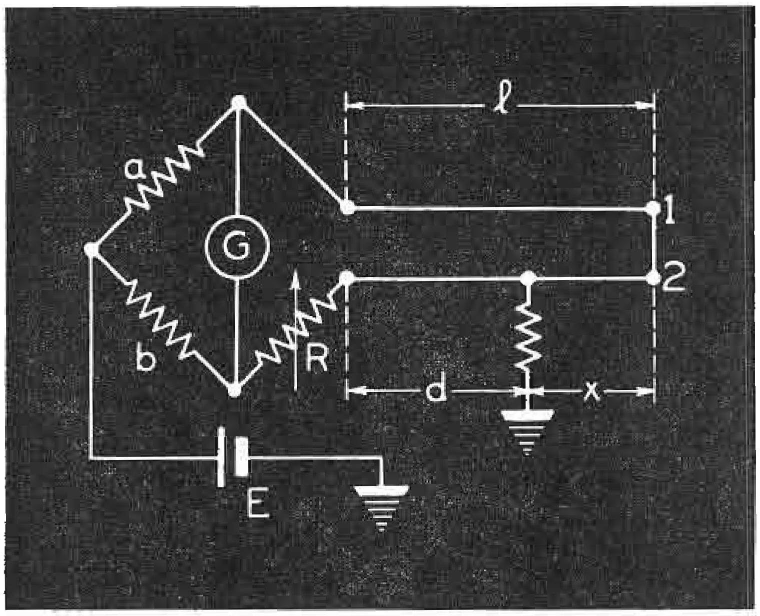


Figure 7

A grounded Varley measurement.

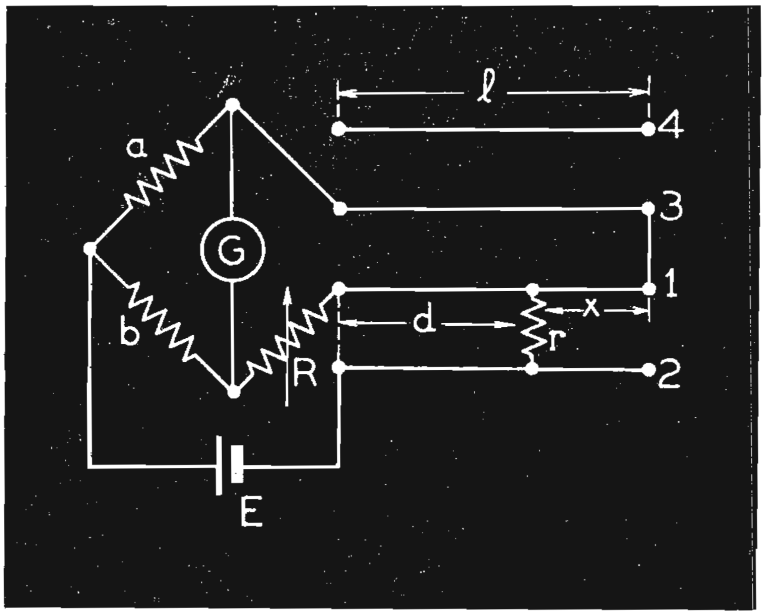


Figure 8

A metallic Varley measurement using a third wire for the battery return circuit; wires *1* and *2* crossed by wire of unknown resistance.

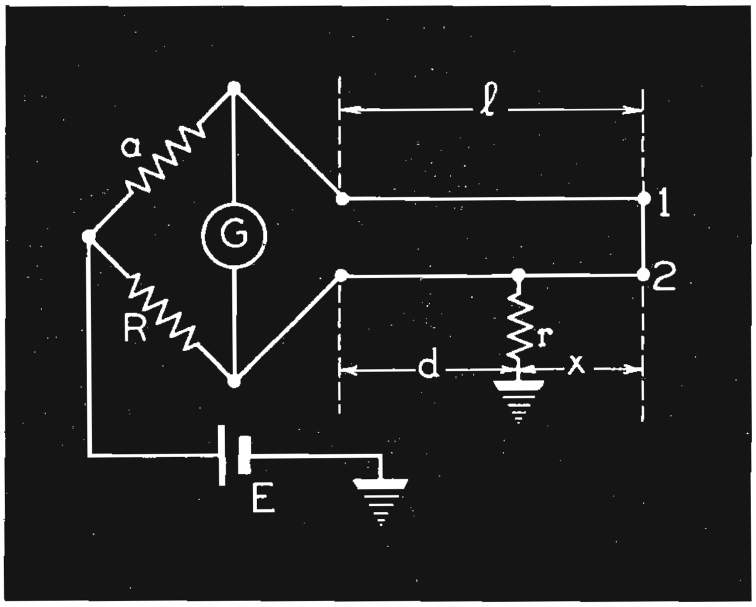


Figure 9

A Murray loop measurement.

*Method 2;* unequal ratio arms, a is not equal to b. Here $R_o = R + d$, $X_o = l + x$, $L = l + x + d$,

$$\therefore l + x = \frac{a}{b}(R + d) \quad (37)$$

and
$$l + x = L - d \quad (38)$$

Equating and rearranging these two equations, and letting X = the ohms in the loop to the fault,

$$X = 2d = 2\frac{bL - aR}{a + b} \text{ ohms} \quad (39)$$

When $a = \frac{b}{4}$, this reduces to

$$X = 0.4(4L - R) \text{ ohms} \quad (40)$$

Subtracting each side of *39* from 2 l,

$$2(l - d) = \frac{2(aR - bL)}{a + b} + 2l \quad (41)$$

but 2 (l — d) = resistance from the far end to the fault = 2 x,

$$\therefore 2x(a + b) = l(a + b) - (bL - aR) \quad (42)$$

and since l = L/2, *42* becomes,

$$2x = 2\frac{aR}{a + b} + \frac{a - b}{a + b} \cdot L \text{ ohms} \quad (43)$$

For the special case of $a = \frac{b}{4}$,

$$2x = 0.2(2R - 3L) \text{ ohms}, \quad (44)$$

the loop resistance from the far end to the fault. In terms of miles, it is only necessary to divide each side of the equations *43* and *44* by *r,* the resistance per loop mile, giving

$$D_x = \frac{1}{r} \cdot \frac{L(a - b) + 2aR}{a + b} \text{ miles} \quad (45)$$

and

$$D'_x = \frac{0.2}{r}(2R - 3L) \text{ miles} \quad (46)$$

from the far end to the fault. By following the same procedure, the number of miles from the near end to the fault may be obtained from equations *39* and *40*.

### Metallic Varley

**Condition . . . one pair out of two crossed with unknown value of resistance (Figure 8).** In this procedure, we take a loop on *1* and *4* or on 1 and *3* as shown. Then we take a Varley using wire *2* to carry the current through the fault which may or may not have some variation. Note that this places the fault outside of the bridge arms and does not affect the balance, although it may affect the sensitivity to a more or less degree. Since this is merely a substitution of a wire for a ground path, all of the equations for the grounded Varley

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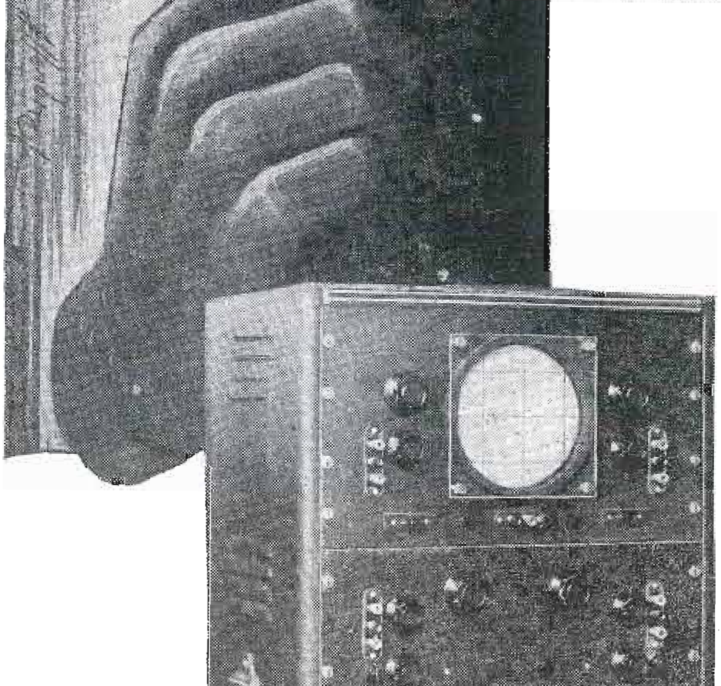

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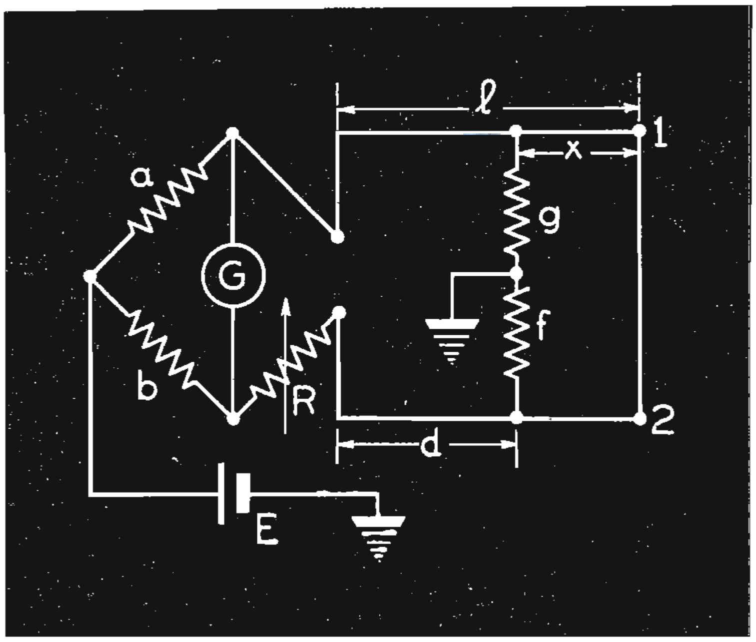



Figure 10
Corrected Varley method.

hold for this case. In general this method is the more reliable where it can be used.

**Varley-Fisher**[6]

This method of measurement (shown by Figure 20), commonly known as the three-Varley method, is useful for the determination of faults when the gauges of the pairs of wires are not the same. This method actually uses two Varley and one loop measurement.

Taking a loop on wires *2* and *3*, and calling this value of $R = R_1$,

$$R_1 = l + d + x \qquad (47)$$

Next, taking a Varley to the trouble, letting this be $R = R_2$,

$$R_2 = l + x - d \qquad (48)$$

Then, taking a Varley into the far end as shown, calling this measurement $R = R_3$,

$$R_3 = l - d - x \qquad (49)$$

Solving these three equations, we obtain,

$$x = \frac{R_2 - R_3}{2} \qquad (50)$$

$$d = \frac{R_1 - R_2}{2} \qquad (51)$$

$$x + d = \frac{R_1 - R_3}{2} \qquad (52)$$

The loop resistances to the fault from the far and near ends are respectively

$$2x = R_2 - R_3 \qquad (53)$$

and

$$2d = R_1 - R_2 \qquad (54)$$

The total loop resistance of the faulty pair is

$$2(x + d) = R_1 - R_3 \qquad (55)$$

Calling the total distance in miles, L, the distance from the measuring end to the fault is by percentage

$$D = L\frac{d}{d + x} = L\frac{R_1 - R_2}{R_1 - R_3}\ \text{miles,} \qquad (56)$$

and from the far end to the fault is

$$X = L\frac{x}{d + x} = L\frac{R_2 - R_3}{R_1 - R_3}\ \text{miles.} \qquad (57)$$

If the resistance per unit distance, $r_1$, is used to obtain the distance, then *53* and *54* may each be divided by $r_1$ to get the actual values. If $r_1$ is in ohms per loop foot, the distances will be in feet, and if in ohms per loop mile, the result will be in miles.

If all wires are of equal resistance, $R_3$ becomes zero and each of the above equations *56* and *57* may be further simplified giving

$$D = L\frac{R_1 - R_2}{R_1} \qquad (58)$$

and

$$X = L\frac{R_2}{R_1} \qquad (59)$$

**Murray Loop Tests**

*Method 1.* This is somewhat similar to the Varley tests, except that arm *b* is removed and *R* substituted in its place, Figure 9.

***Condition . . . one wire of a pair grounded.*** In this procedure we connect as shown in Figure 9.

Here $X_o = l + x$, $R_o = d$, $b = R$; therefore

$$l + x = \frac{a\,d}{R} \qquad (60)$$

but

$$d = l - x \text{ or } x = l - d, \qquad (61)$$

then

$$\frac{R}{a} = \frac{l - x}{l + x} \qquad (62)$$

Solving for x and placing on a loop resistance basis,

$$2x = 2l\frac{a - R}{a + R}\ \text{ohms, the} \qquad (63)$$

loop resistance from the far end to the fault, $2l = L$, the total loop resistance,

$$\therefore D = L\frac{a - R}{a + R}\ \text{ohms} \qquad (64)$$

The distance from the measuring end is found by subtracting each side of *64* from *L*, the total loop resistance, calling this X,

$$X = L\frac{2R}{a + R}\ \text{ohms} \qquad (65)$$

*Method 2.* This is the better method of the two as the resistance per mile need not be known, nor does the loop resistance need to be known. Letting

l = distance between terminals
x = distance from distant point to fault
r = resistance per linear mile, and
d = distance between the measuring end and the fault.

Here, $X_o = r(l + x)$, $R_o = r(l - x)$, $b = R$,

then

$$R\,r(l + x) = a\,r(l - x) \qquad (66)$$

or

$$\frac{R}{a} = \frac{l - x}{l + x} \qquad (67)$$

Solving for x, the distance from the far end to the fault

$$x = l\frac{a - R}{a + R}\ \text{miles} \qquad (68)$$

Now $l - x = d$, the distance from the measuring end,

$$\therefore l - x = \frac{2Rl}{a + R}\ \text{miles to the fault} \qquad (69)$$

**Swings and Hits**

These measurements are made in the same manner as given before. But to assist the tester, a buzzer, relay or a light can advantageously be inserted in the battery lead with the bridge set up for a Varley measurement. If the fault resistance is very high, this may not be of any value however.

**Corrected Varley**[6, 7]

***Condition . . . leaky cable wires with unequal resistance to ground at the fault location, with g > f by at least 25%, and conductors of the same gauge.***

Connections are shown in Figures 10 and 11, also simple loop measurements from each end of the faulty wires, as shown in Figure 6, with the opposite ends of the wires open. In this case, the loops are completed through the fault.

Considering Figure 10, let

E = battery voltage used.
x = resistance of either wire from the distant end to the fault.
l = resistance of either wire between stations.
f + g = sum of the effective resistances of the two wires to ground.
a = b = ratio arm resistances.
R = adjustable resistance to bring the galvanometer reading

to zero, or a balanced condition.

The portion of Figure 10 composed of resistances f and g, and conductor resistances of x ohms, each form a $\pi$ or delta network which may be transformed into an equivalent T network as shown in Figure 11. The effect of the shunt arm of the T is to lower the sensitivity of the bridge for a given galvanometer, with fixed battery potential as pointed out in the discussion on bridge sensitivity. This is because the available voltage effective for measurement purposes is less than the battery voltage, by the amount of loss caused by the sum of the voltage drops across . . . (1)—the internal resistance of the battery, (2)—the ground resistance, and (3)—the resistance of the shunt arm of the equivalent T network.

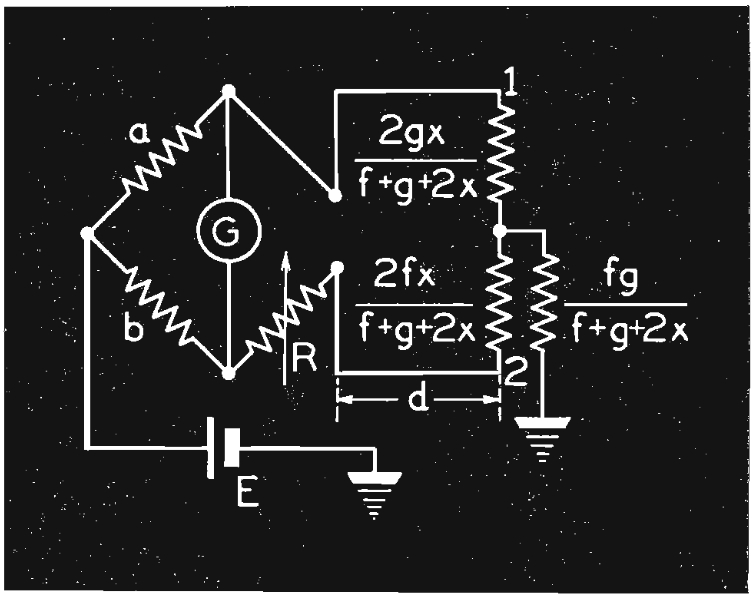



Figure 11

Corrected Varley method equivalent of Figure 10.

Here, we have

$$R_o = R + d + \frac{2fx}{f+g+2x} \quad (70)$$

and $$X_o = d + \frac{2gx}{f+g+2x} \quad (71)$$

which give, with a = b, and d = l — x, the equation of balance,

$$(l-x) + \frac{2gx}{f+g+2x} = (l-x) + \frac{2fx}{f+g+2x} + R \quad (72)$$

Solving this for the loop resistance to the fault, from the distant end,

$$2x = R\left(\frac{f+g}{g-f-R}\right) \text{ ohms} \quad (73)$$

The quantity in parenthesis therefore represents a correction factor by which the Varley measurement, R = V, must be multiplied to obtain the true Varley or loop from the far end. Since neither of the quantities *f* or *g* are known, two additional and independent equations must be used to evaluate the quantity 2 x. These are readily obtained by making first a loop, then a Varley measurement into the trouble from the far end with the near end of the wires open. Calling the loop $L_o$, and the Varley $V_o$ for these conditions,

$$f + g = L_o - 2x \quad (74)$$

and $$g - f = V_o \quad (75)$$

Substituting *74* and *75* in *73*, the resistance from the far end to the trouble is

$$2x = \frac{L_o}{V_o} \text{ ohms} \quad (76)$$

and from the near end to the fault is

$$2(l-x) = 2l - R\frac{L_o}{V_o} \text{ ohms} \quad (77)$$

If the conductor resistance (corrected for temperature), is r ohms per loop foot, the distances are given as

$$D = \frac{2x}{r} = \frac{R\,L_o}{r\,V_o} \text{ feet} \quad (78)$$

and

$$X = \frac{2(l-x)}{r} = \frac{2l}{r} - \frac{R\,L_o}{r\,V_o} \text{ feet} \quad (79)$$

from the far and near ends respectively. In addition to the restrictions above imposed for accuracy, it is necessary that the fault resistances remain constant during the period of measurement. Further, to obtain the value of r, either records or calculations must be resorted to, unless spare pairs are available from which to obtain more accurate data for location of the faults. If the value of the loop resistance $L_o$ is greater than the value of *R* when a = b, the ratio may be changed and $\frac{a}{b} L_o$ substituted in the equations *74* to *79* wherever it appears.

### Straight Resistance

*Method 1*[7]. This method assumes that the wires have equal resistance per conductor and have the same value of leak to ground, or in Figure 10, that f = g. Also, the values of f and g are assumed to remain constant during tests. With the condition of Figure 10 with f = g, two loop measurements may be made, one from each end with the opposite ends open, and we may write, using, f + g = h, and calling the loop measurement $L_o$,

$$a_1 L_{o1} = b_1 [2(l-x) + h] \quad (80)$$

and $$a_2 L_{o2} = b_2 [2x + h] \quad (81)$$

where the subscripts refer to measurements made at ends *1* and *2* respectively. Solving *80* and *81* for the loop resistance to the fault from end *2* (the far end), by subtracting the second from the first, and simplifying,

$$2x = \frac{1}{2}\left[2l - \frac{a_1}{b_1}L_{o1} + \frac{a_2}{b_2}L_{o2}\right] \text{ ohms.} \quad (82)$$

Since 2 d is the loop resistance from end *1* to the fault and 2 d = 2 (l — x), using *82* with this, we get

$$2d = 2(l-x) = \frac{1}{2}\left[2l + \frac{a_1}{b_1}L_{o1} - \frac{a_2}{b_2}L_{o2}\right] \text{ ohms.} \quad (83)$$

When equal ratio arms are used at the two ends, $a_1 = a_2 = a$ and $b_1 = b_2 = b$, and *83* becomes

$$2d = \frac{1}{2}\left[2l - \frac{a}{b}(L_{o2} - L_{o1})\right] \text{ ohms.} \quad (84)$$

and finally, when a = b, from *84*

$$2d = \frac{1}{2}[2l - (L_{o2} - L_{o1})] \text{ ohms.} \quad (85)$$

*Method 2.* This method assumes the same conditions as Method *1* and is subject to the same limitations, but permits measurements to be made from one end only. It thus possesses the advantage of requiring only one bridge. This method may also be used to determine the valve of a high resistance to low resistance cross when a suitable ground connection is not available at the far end. When such ground connections are available, it is much more satisfactory and reliable to use the regular grounded or metallic Varley type of measurement.

### Bibliography


[1]*Electrical Measurements,* Curtiss; McGraw Hill Book Co.
[2]*Resistance Manual,* Wilbur B. Driver Co.
[3]*Principles of Electricity,* Page and Adams; D. Van Nostrand Co.
[4]*Electricity and Magnetism,* Starling; Longmans Green and Co.
[5]*Elements of Electricity,* Timbie; John H. Wiley and Sons, Inc.
[6]*Cable Testing* (P.O.E.E. paper No. 104), E. S. Ritter; Jan. 17, 1923.
[7]*Bridge Methods for Locating Resistance Faults on Cables,* T. C. Henneberger and P. G. Edwards; B.S.T.J. Vol. X, pp. 382; July 1931.

**REMINISCENCES**

"THE picture of the early deForest receiver in the 1906 Key West station that appeared in the October, 1943, issue of COMMUNICATIONS sure brings back memories," wrote Roscoe Kent in a recent letter.

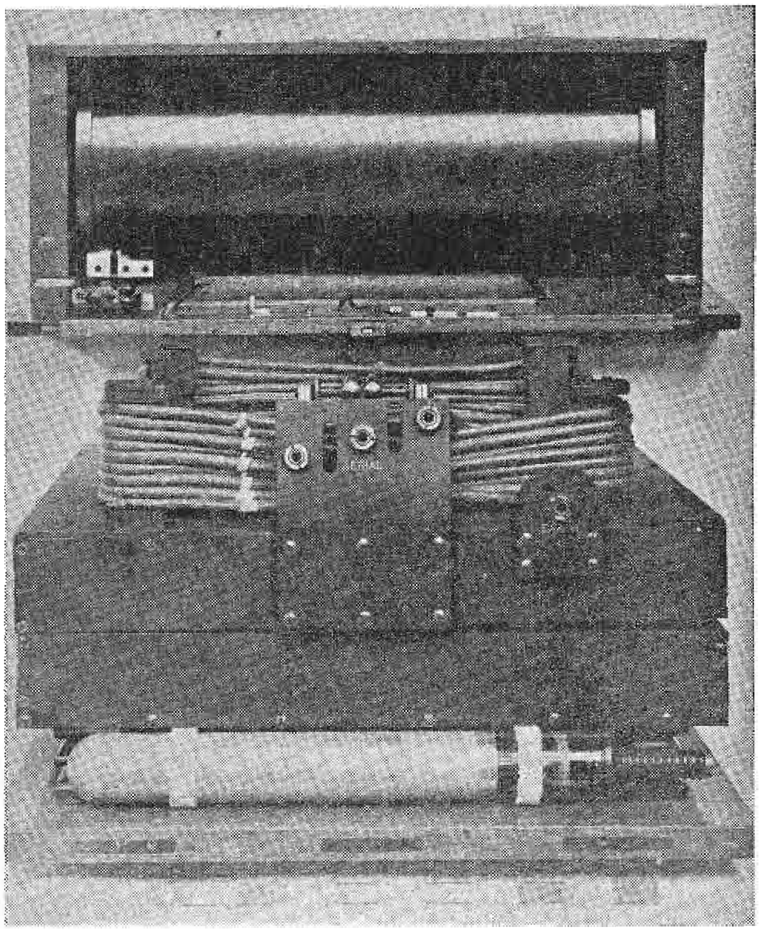
"In those days we simply twisted the knobs of the tuners and variables until we located a station, and then marked the locations of dials on the boxes or a sheet until the station changed its gap length or location of helix clips. Then we would hunt again.

"In those days a 35-kw station took up hundreds of square feet of floor space for the Hornsby-Akroid oil engines, Bullock generators, plate glass and tin-foil condensers, solenoid switch in oil operated by the key, and the hand-adjusted spark gap in the helix as big as a barrel. And the antennae system took miles of wire which had to be repaired from a boatswain's chair after climbing the old wooden masts.

"Then we were sailors, carpenters, oil engineers, electricians, cable splicers, riggers, wig-wag men, machinists, telegraphers, cooks and chambermaids, all in one.

"Joe Watts, V. Ford Greaves and the writer, built old 'Si' at Guantanamo, from the ground up, including the buildings and masts, under Frank E. Butler for Doc deForest and 'old man' Elliott.

"Would like to hear from any of the oldtimers who used to be at Key West and Colon in the old days when the above two stations with Guantanamo were the 'biggest wireless stations in the world.'"



One of the early models of spark transmitters used by the late Marconi. This unit was produced around 1912.

*(Courtesy Clark Radio Library)*

ED G. RASER writes in to say that during the past two years he has been traveling about all over this country. At present he is with the New Jersey State Police Communication System, Radio Division, in charge of all f-m transmitters and equipment in Troop C. He was formerly with the Signal Corps, engaged in engineering development and field test work.

According to a letter received by Ed, Willard S. Wilson, formerly of Wilmington, Delaware, is now a Major in the 10th U. S. Air Force located somewhere in India. He is a communications officer there, and would very much like to have the boys write to him. His full title and address is: Major Willard S. L. Wilson, Headquarters, 10th U. S. Air Force, APO 855, New York. Ed and Willard were in the Navy in 1917.

MANY a reminiscent story were told at the recent Armed Services Christmas party held in New York. We learned, for instance, that Herman G. Berger, who is now a control engineer at WOR and who started back in the spark days, is the owner of the first tube ever modulated over WJZ. . . . Edward A. Carroll, who is now at WCAU, Philadelphia, and has been there since 1931, told of his early days in the Coast Guard in 1920, and then later in the Merchant Marine from '21 to '28. . . . Oldtimer E. D. VanDuyne, in radio since 1919 when he worked with A. H. Grebe, was at the party too. He is now with RCA as a field engineer. . . . Jim Maresca, a VWOA charter member, recalled his Signal Corps days during the first World War. From the RCA Frequency Bureau executive, H. C. Wilks, we learned of the 1922 days of radio. . . . Announcer Roger Lum, who was a radio ham in 1914, revealed many interesting anecdotes of that period. Roger was a commercial operator in 1918. In 1922 he went to WJZ, Newark, doubling as watch operator and announcer. This was followed by studio managership at WRC.

A COMPLETE report on the 19th annual dinner-cruise held in the Hotel Astor will appear in the March issue of COMMUNICATIONS. This year's affair appears to be the largest we've had the pleasure of running in a long time. . . . By the way, the Yankee Chapter is honoring Ted McElroy at their annual-cruise in Boston, for his developments. He will receive a suitable scroll at the dinner, which will be given on February 26th.

# NEWS BRIEFS OF THE MONTH ...—

### STANDARD FREQUENCY BROADCAST CHANGES

Two changes in the standard frequency broadcast service of the National Bureau of Standards have been announced. One is the addition of a new radio frequency, 2,500 kilocycles per second, at night. The other is omission of the pulse on the 59th second of every minute.

* * *

### G. E. TO BUILD 40-KW TELEVISION STATION FOR WGN

General Electric has been commissioned to build a 40,000-watt television transmitter and elaborate studio equipment for WGN, Chicago, to be delivered after the war or as soon as priorities, as determined by the War Production Board, permit its construction.

* * *

### HENRY JOHNSON NOW LT. IN NAVY

Henry C. L. Johnson, former advertising manager of the radio division of Sylvania Electric Products Inc., has been promoted to the rank of full lieutenant in the United States Navy.

* * *

### LODGE NAMED ACTING ENGINEERING DIRECTOR OF CBS

William B. Lodge has been named acting director of the CBS general engineering department.

Lodge, a graduate of Massachusetts Institute of Technology, joined the Columbia Broadcasting System in December, 1931, as a technician. In 1934 he became a member of the network's general engineering department, and three years later was named engineer in charge of the radio frequencies division.

* * *

### D. W. MAY FORMS OWN DISTRIBUTING UNIT

D. W. May has resigned as Eastern regional manager of the electronics department of G. E. and formed a new distributing company, D. W. May, Inc., 1 East 42 Street, N. Y. City.

First connection announced for the new firm is the exclusive franchise for distribution of Farnsworth Television and Radio for the entire metropolitan market including New York and New Jersey.

* * *

### CHANGE IN SMPE CONFERENCE DATES

The Society of Motion Picture Engineers will hold its 55th semi-annual technical conference at the Hotel Pennsylvania. New York, April 17, 18 and 19, instead of April 25-27, as previously announced.

* * *

### N. A. PHILIPS BUYS PHILIPS METALIX

North American Philips Company, Inc., Dobbs Ferry, New York, has purchased the assets and factory of its affiliate, Philips Metalix Corporation.

Philips Metalix Corporation has been manufacturing x-ray tubes and equipment for the medical profession, hospitals, industry and the government since 1934. The business will continue as the Metalix Division of North American Philips Company, Inc.

### PIERCE ELECTED WGAR V-P

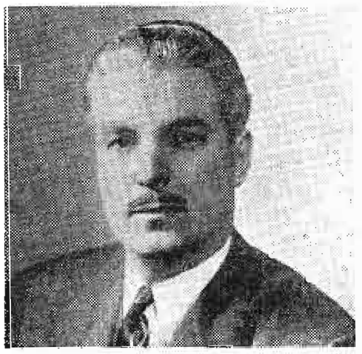
R. Morris Pierce has been elected vice president in charge of engineering of stations WJR, Detroit; WGAR, Cleveland, and RMPC, Los Angeles.

Mr. Pierce has been WGAR chief engineer for thirteen years. He served as chief engineer in the Psychological Warfare Branch, U. S. Army in North Africa and Sicily for seven months last year and is currently on leave again.

* * *

### CONNOR NOW WEST COAST SYLVANIA MANAGER

George C. Connor, Sylvania Electric Products, Inc., field engineer, has been appointed manager of the California division of the equipment tube sales division. Mr. Connor's headquarters will be in the Los Angeles office, 555 South Flower Street.



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### UNIVERSITY SPEAKERS USED IN KISKA LANDING

American-Canadian forces invading Kiska recently, used a public address system in their landing operations. This p-a equipment included reflex speakers made by University Laboratories, 225 Varick Street, N. Y. 14, N. Y.

### ALLEN DU MONT ELECTED TELEVISION ASSOCIATION PRESIDENT

Allen B. DuMont, president of Allen B. DuMont Laboratories, Inc., has been elected president of the newly formed Television Broadcasters Association, Inc. Other officers elected were: Lewis Allen Weiss, Don Lee Network, vice president; Jack Poppele, station WOR, New York, assistant secretary-treasurer.

Directors elected for three years include O. B. Hanson, NBC; E. A. Hayes, Hughes Tool Company, and Paul Raibourn, Paramount Pictures. Elected as directors for two years were Worthington Miner, CBS; Robert L. Gibson, General Electric Co., and Lewis Allen Weiss, Don Lee Network. F. J. Bingley, Philco, Allen B. DuMont, and E. W. Mason of Earle C. Anthony, Inc., were elected to one year terms.

The organization voted to join the RTPB as a sponsoring member.

* * *

### GLASS INSULATORS APPROVED

The American Standards Association has announced the approval of a new American war standard for glass radio insulators (C75.8-1943).

These specifications cover the performance requirements, test methods, and standard dimensions for a standard series of glass insulators of the quality required by the Army and Navy. The basic specification for glass material is the American war standard ceramic insulating materials, Class L, C75.1-1943.

* * *

### CHICAGO TO HAVE NEWA WAR CONFERENCE IN APRIL

The second War conference of the National Electrical Wholesalers Association will be held at the Stevens Hotel, Chicago, Illinois, April 19th to April 22nd. Charles G. Pyle, Managing Director of NEWA, indicated that the war conference will include a complete review of the membership's participation in the many phases of the war program, and a report of the postwar planning committee.

* * *

### MORE TELEVISION RECEIVERS TO WOUNDED VETERANS' HOSPITALS

Forty-five television receivers are being installed in hospitals for wounded service men by NBC and RCA, in cooperation with G.E. These receivers are in addition to the first ten RCA instruments which have been in operation in six hospitals since last November.

* * *

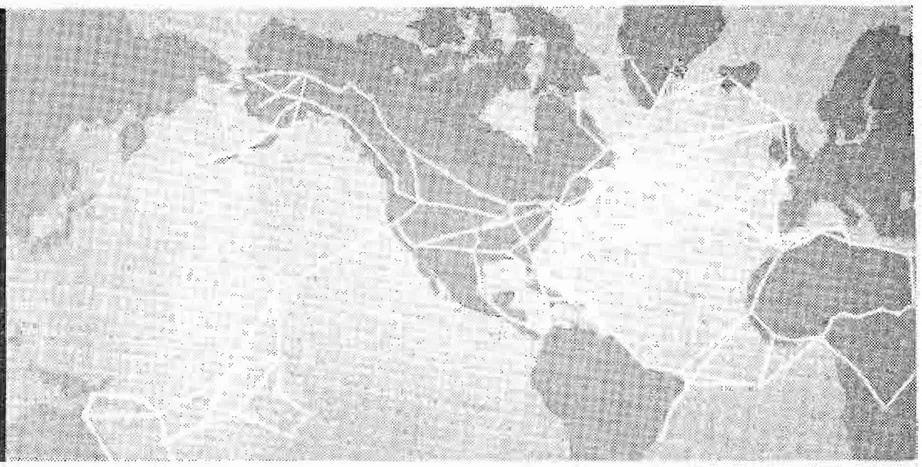
### DR. A. W. HULL RETIRES AS AMERICAN PHYSICAL SOCIETY PRESIDENT

Dr. Albert W. Hull, assistant director of the G. E. Research Laboratory, retired recently as president of the American Physical Society. In his address at Columbia University he said that physical science can provide for the ill of unemployment in the postwar world.

Dr. Hull mentioned the electric industry which, as the result of research, has reduced the cost of electric power and lamps, and has produced such new products as x-rays, radio, refrigerators, etc.,

*(Continued on page 86)*

# *Serving* . . . THE WORLD'S GREATEST AIRLINE —



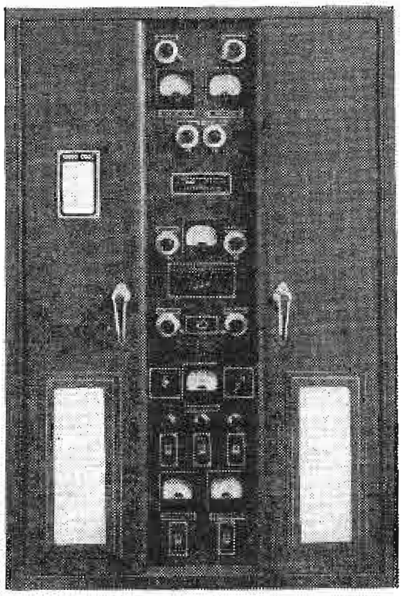
*Routes of the World's Largest Airline . . . the Army Air Forces Airways*

*Signal Corps Photo*
*Airdrome Traffic Control Tower somewhere along the lines of the Army Air Forces. Operated by the Army Airways Communications System Wing. Maintains two-way communication between airfield and aircraft.*

**Our Proudest Achievement —** A gigantic network of air routes—more than 100,000 miles of communications, landing fields and supply depots —*that's the Army Air Forces Airways.* RADIO RECEPTOR'S contribution to the equipment of the radio life-line of these airways is its proudest achievement. Developed in pre-war days . . . refined and simplified in the crucible of conflict, RADIO RECEPTOR airway and airdrome equipment will be ready, when victory comes, to doff its war paint and resume civilian dress.

**Plan Now for Victory —** Although our entire production now goes to the Army Air Forces, the Signal Corps and other war agencies, our engineers will be glad to confer with you on your plans for peace. The 6,000 new airports, estimated by the CAA as needed by the country, will require virtually the same type of equipment which is being supplied to the military services. To the thousands of municipalities planning the expansion of existing airports, or the construction of new ones, we offer our experience.

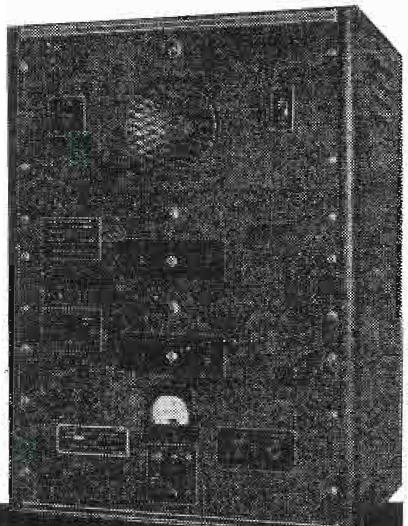
Write for our interesting, non-technical booklet, "Highways of the Air", which explains the importance of radio to aviation. Desk C-2.



*Transmitter for Airport Traffic Control.* ▶ *Output rating 50 watts, Frequency range 116 to 126.25 megacycles.*

ARMY E NAVY — *Awarded for Meritorious Service on the Production Front.*

***SPEED THE DAY OF VICTORY BUY MORE WAR BONDS***



*Control Cabinet Assembly. Consists of* ▶ *transmitter remote control unit, loud speaker and two fixed frequency airport receivers.*

**RADIO RECEPTOR CO., INC.**

Engineers and Manufacturers of Airway and Airport Radio Equipment

251 WEST 19th STREET
NEW YORK 11, N. Y.

SINCE 1922 IN RADIO AND ELECTRONICS

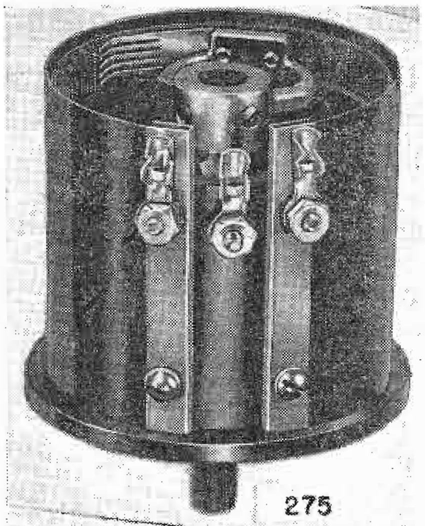
# THE INDUSTRY OFFERS . . . — . . . — . . . —

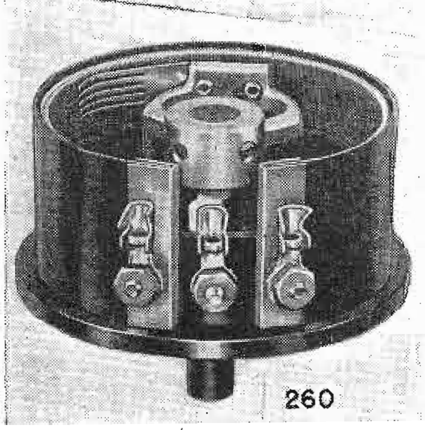
### DE JUR POTENTIOMETERS

Precision potentiometers which are said to operate for 2,500,000 revolutions at 360° continuous rotation in both directions, for 24 hours a day, have been announced by DeJur-Amsco Corporation, Shelton, Conn.

Resistance wire on these potentiometers are space-wound on a strip of fabric base bakelite on special machines. The strips are then coated with a bonding agent which bonds the wire to the strip. After this, a protective bakelite band is placed externally over the fine wire strip, securing the wire against mechanical damage or derangement. It is next bent around and fastened to the bakelite supporting form. Constant contact resistance and low noise level are said to be maintained for any position of the knob through the use of separate wiping fingers.

Types 261, 281, 291, 276, 292, and 296 have top wipers which are provided for the highest types of accuracy and for the closest tolerances. Designed as low operating temperature type, as defined by the American Standards Association.

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### AVERY ADHESIVES

Industrial pre-cut masking stickers that can be applied without moistening and peeled off without scraping or tearing have been announced by Avery Adhesives, 451 East 3rd Street, Los Angeles 13, California.

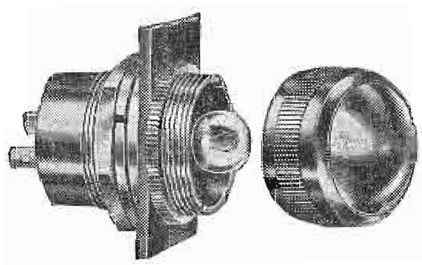
### DIALCO PILOT LIGHT ASSEMBLY

A new pilot light assembly known as the *Compacto,* is now available from the Dial Light Co. of America, 90 West Street, N. Y. City. The unit is intended to serve two primary purposes: (1)—to adapt a large jewel holder to a panel where mounting space behind the panel is limited, and (2)—to provide a large surface light on a low voltage panel.

Made of brass, or aluminum, with the socket housing made of Navy specification bakelite sealed with bakelite varnish. Screw-in type jewel holder.

Finishes may be any of a choice of seven approved platings. Lenses may be smooth or diamond-faced; if smooth, they may be clear color, sandblasted on back, or sandblasted over-all. Lens colors may be red, green, amber, blue, yellow, opal, white or clear. Trademarks, numerals, letters or special signals may be incorporated in the jewel assembly.

The unit has silver-plated vibration-proof terminals, and may be had grounded or ungrounded. The socket accommodates the following lamps in all voltages: T3¼ miniature bayonet base single contact lamps; TS-53 miniature bayonet base lamps, and Mazda 51 G3½ miniature bayonet base lamps.



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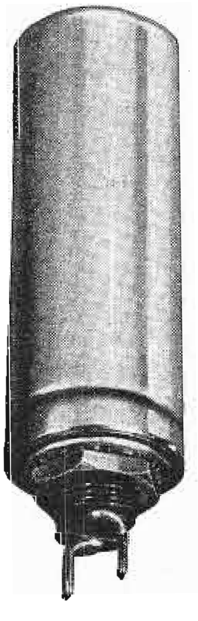
### OIL TYPE CAPACITRONS

Heavy duty 3- and 4-mfd oil type capacitors with d-c working voltage ratings from 600 to 1,500 are now being manufactured by Capacitrons, Inc., 318 West Schiller Street, Chicago 10, Illinois.

A bakelite neck is lock-spun into an extruded, insulated metal container. Grounding of either insulated terminal is accomplished with a special ground-lug. Units are 1½" x 4½".

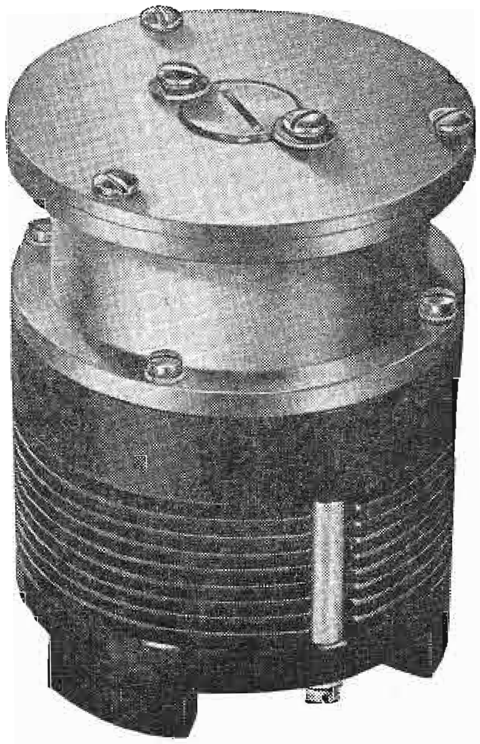


### WEBSTER VOLTAGE REGULATOR

A high-wattage voltage regulator VR-2200, has just been released by Webster-Products, 3825 West Armitage Avenue, Chicago 47, Illinois. The regulators are of the carbon pile style, and are said to dissipate 300 to 400% more power than previous conventional designs, yet occupy the same chassis space, with 8% less cubic volume. They are 6% heavier.

Many different applications are said to be possible. In one, the resistance of the carbon pile is in one side of the line and the regulator operates to vary this resistance automatically so as to produce constant voltage across the load. In another typical application, the voltage regulator varies the field excitation of an inverter, alternator or special dynamotor in such a manner as to produce constant output voltage across the load. Where the device is delivering a-c, a rectifier may be provided to supply the regulator solenoid circuit.

The VR-2200 units will handle 100 watts in the pile with an air flow through the fins of approximately 25 cubic feet per minute, and up to 50-75 watts without air blast. Piles can be provided with a resistance range of the order of 20 to 1, the total range of maximum values being from less than 1 ohm to about 100 ohms.



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### GROOVED FLUX WIRE SOLDER

A new type of fluxed wire solder, Fluxrite, which contains flux in longitudinal grooves on the surface rather than in the conventional core, has been announced by the National Lead Company, 111 Broadway, N. Y. 6, N. Y.

Since the flux is outside rather than inside, it liquefies and flows onto the

(*Continued on page* 82)

## THE INDUSTRY OFFERS . . . —

(*Continued from page* 80)

work before the solder melts, according to the manufacturer.

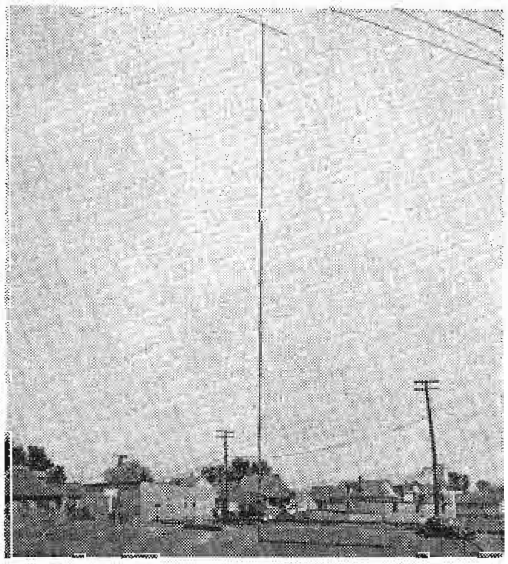
The new product comes in the same diameters as regular cored solder. It is available in two compositions designated as *red stripe* and *green stripe*. These designations refer to the color of the flux which has been dyed in each case for easy identification.

* * *

### HARCO TELESCOPIC MAST

A telescopic 90-foot mast that is said to withstand a wind pressure of 125 miles an hour and can be erected from ground anchors to top cross-arm in about an hour has been announced by the Harco Steel Construction Co., 1180 E. Broad St., Elizabeth, N. J. The mast is also available in heights from 25 feet up to 200 feet.

Smallest section of the 90-foot mast is 3¼" in diameter and the sections increase to 4½" in the center. The unit, complete with cross-arm of approximately 8 feet, takes less than 12 cubic feet of shipping space when dismantled. Weight 750 pounds, exclusive of shipping containers.



* * *

### ACME ISOLATING TRANSFORMER

An isolating transformer that eliminates interference affecting test work has been produced by Acme Electric and Manufacturing Company, Cuba, N. Y.

The transformer has a secondary that is completely enclosed in a copper shield. Secondary terminal connections are provided by means of a lead shielded cable,



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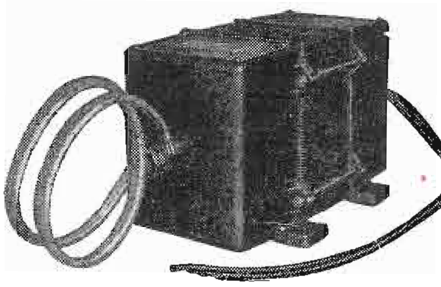
the sheath of which is integrally joined to the copper enclosing shield of the secondary winding.

Normally rated at 2 kva, the unit is said to be capable of handling an over-load of 50% or a total load of 3 kva. The regulation of the transformer is 1% at 1 kva. The lighting in the shielded test-room, the use of soldering irons, instruments and various types of test equipment may all be operated from the shielded secondary of the transformer without causing objectionable voltage drop. The use of instruments or equipment may be used as the need requires, the load being switched on and off without affecting the relatively constant voltage necessary for accurate testing.

This transformer type T-4173, weighs approximately 123 pounds; has a length of 18¼", height of 9¼", and overall width of 10 7/16", with mounting centers of 6 15/16" x 9⅛". Also available in sizes of 1 kva and ½ kva.



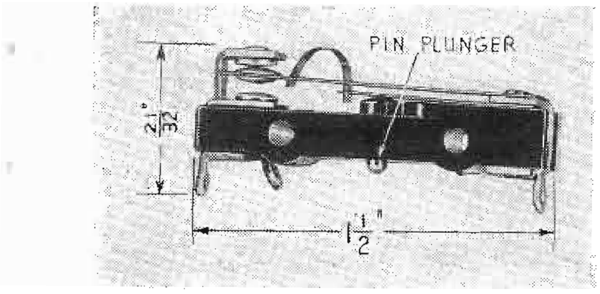
* * *

### ONE OUNCE ACRO MIDGET SWITCH

A 1-ounce snap midget switch built on the rolling spring principle, 9/16" wide and 7/16" thick, has been developed by the Acro Electric Company, 1319 Superior Ave., Cleveland 14, Ohio.

The switch is designed for actuation from either the top or the bottom. Both the snap-action spring itself and the center blade are made of beryllium, while the base is of bakelite. Under factory tests the switch has shown no failure after 94 million operations. When built into relays, smaller coils may be used as only 4 to 6-ounce operating pressure is required.

Furnished in single pole, normally open, normally closed, and double throw with both pre-travel and over-travel provided.




* * *

### CLARK QUARTZ CRYSTAL CUTTING TABLE

A quartz orientation replacement table, that is said to be adaptable to any quartz cutting saw, has been announced by the Robert H. Clark Company, 9330 Santa Monica Boulevard, Beverly Hills, California. The table is used in positioning the quartz to facilitate extreme accuracy for cutting crystals.

The table can be rotated 360° and provisions are made for the *X* correction

(*Continued on page* 84)

## THE INDUSTRY OFFERS . . . —

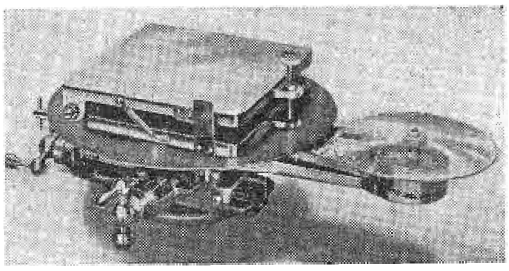
(*Continued from page* 83)

with a conveniently located scale and pointer.

Spring-loaded gears in the gear-train are said to eliminate back-lash. The gears on the sector-arm and the gear-train are meshed under constantly maintained tension to eliminate any inaccuracies due to tooth wear.

Gear case is protected by a Lucite cover to prevent quartz loaded coolant from getting into the precision gear mechanism.

Simple cross-adjustments are provided under the table for positioning horizontally. Screw and scale are provided for tilt adjusting the top plate.



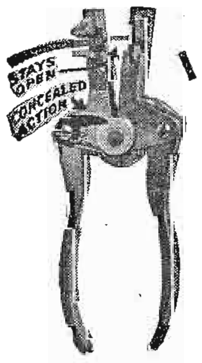
* * *

### GENERAL CEMENT WIRE STRIPPER

A wire stripper with an improved automatic *stay open* feature that is said to facilitate stripping insulation from very fine stranded wires has been announced by General Cement Mfg. Co., Rockford, Illinois. The mechanism of the new tool, known as the Speedex Wire Stripper, is designed to hold the jaws of the stripper open until the wire is removed.

The stripper removes insulation from all types of solid or stranded wire from No. 8 to No. 30. It can be used to cut wire when desired. Approximately 750 to 1,000 wires can be stripped per hour by the average operator, according to the manufacturer.

Hardened steel precision ground cutting blades can be purchased separately.




* * *

### ALLIED CONTROL TELEPHONE TYPE RELAYS

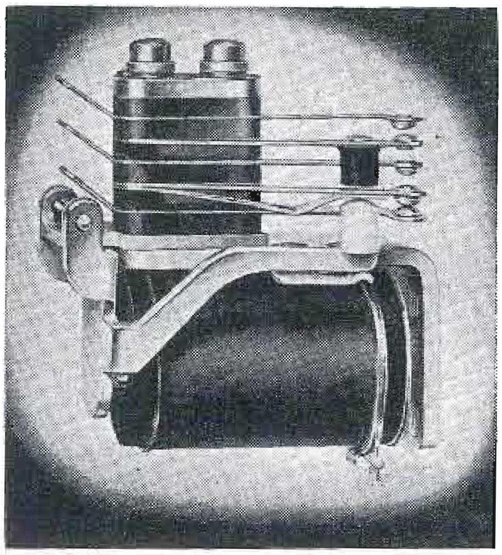
A relay, model TSU, for bottom mounting, specifically designed for crystal switching, and suitable for various high frequency, plate circuit and general utility applications, is now available from Allied Control Company, Inc., 2 East End Avenue, New York 21, New York.

Contact arrangements can be supplied normally open, normally closed, single pole double throw, or in any two combinations. The contacts will carry two amperes at voltages to 24 volts d-c and 115 volts a-c, non-inductive load. Coil resistances are available from a fraction of an ohm to 5,000 ohms.

These relays are said to be capable of withstanding vibrations up to 10 G.

A model, TSL, is also available for end mounting. Both TSU and TSL types are available with ceramic or bakelite insulation. Their overall dimensions are 1¼" x ¾" x 1½"; weight, 1¼ ounces.

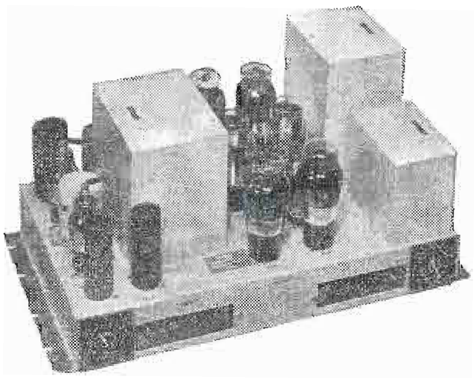
* * *



* * *

### LANGEVIN AMPLIFIER

An amplifier with inherent noise level 68 db unweighted below full output of plus 47 vu at 2 per cent rms harmonic distortion is announced by Langevin Company, Inc., 37 West 65th Street, N. Y. 23, N. Y. With an input impedance of 600 ohms, the gain is 60 db. Using bridging input, the gain is 46 db. Output impedance is adjustable 1 to 1,000 ohms. Gain versus frequency and power output versus frequency characteristics are available upon request.



* * *

### FONDA CELLOPHANE-TAPE RECORDER AND PLAY BACK

A sound-recording and play-back unit, using cellophane tape, and capable of up to eight hours of recording, was recently announced by the Fonda Corporation, 245 East 23rd Street, N. Y. 10, N. Y.

The tape used is a little more than an inch in width. It is an endless loop 320 feet long and permits up to eight hours of constant recording.

The recorder is a development of Jay Fonda, chief engineer of the corporation. A yieldable felt bed directly under the recording needle is used in Fonda's system.

The tape, which is about twice the thickness of ordinary cellophane, runs under the needle at a rate of about 40 feet a minute and is capable of carrying 60 parallel grooves. Both the recording and reproducing needles have permanent gem points.

At present three models are available;

(*Continued on page* 106)

## NEWS BRIEFS

(*Continued from page 78*)

which gave employment to hundreds of thousands.

As a yardstick for the value of new products, he cited the screen-grid tube. "Radio receivers were made without it," he said, "and could be now, but they would require twice as many tubes and circuit elements, and would cost twice as much. The American people spent four-hundred-million dollars for radio receivers in 1941. Without screen-grid tubes the cost would have been double that value. Hence, the tube saves the public $400,000,000 a year."

* * *

### WOMEN AND MEN SHARE IN G.E. PRODUCTION AWARDS

Top production ideas during 1943 went to women war workers as well as men at General Electric plants. The women employees, many of them new in industry, added to the total of accepted manufacturing suggestions, thus raising the awards granted to 47% above the previous year's all-time G. E. high.

Mrs. Edith Hogan of the West Lynn, Massachusetts plant received the highest single award for suggesting the marking of instrument dials mechanically rather than by hand, thus saving four hundred *woman-hours* a week.

Mrs. Anna Turnbull of the Bridgeport, Connecticut plant received a substantial award for suggesting that cotton wrappings on military communications devices be burnt off rather than scissored off.

Anthony Szot of the Schenectady plant received the greatest portion of the awards. His suggestions included methods for reducing four operations to one in machining various models, and for eliminating a roughing operation.

Other suggestions covered methods of finishing, reusing skids, winding, rotating elements, etc.

* * *

### MALLORY CATALOG

A 36-page 1944 edition of the catalog on parts and accessories has just been issued by P. R. Mallory & Company, Inc., Indianapolis, Indiana.

Data in this new edition covers attenuators, battery boosters and chargers, bias cells, r-f chokes, paper and dry electrolytic capacitors, rheostats, variable resistors, volume controls, etc.

A section is also devoted to the Mallory vibrapacks. A base diagram chart as well as a replacement chart for the interrupter and synchronous type vibra-

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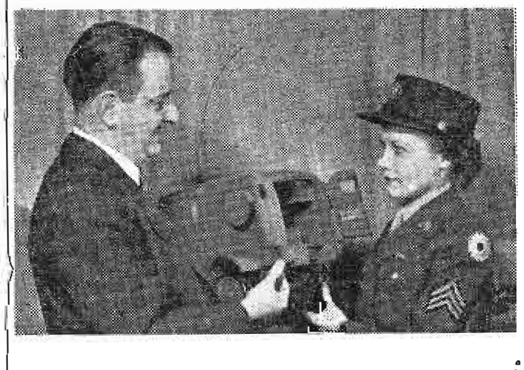
### SCR-299 REPLICA



WAC Sergeant Mary Jane MacGuire and William J. Halligan, president, Hallicrafters, Inc., inspecting the display model of the Signal Corps' mobile radio unit, Hallicrafter SCR-299, part of the Signal Corps Production Incentive exhibit now on tour of war plants.

tors is also included. This chart covers replacement data for a variety of receivers and also supplies physical and electrical specifications for various type Mallory vibrators.

* * *

### LIP MICROPHONE FEATURED IN BAKELITE REVIEW

The currrent issue of the Bakelite Review, published by Bakelite Corporation, 30 East 42nd Street, New York 17, contains an interesting analysis of the lip microphone now being used in the armed services.

This issue also contains data on plastics in relays, antenna loops, etc.

* * *

### HOFFMAN JOINS MACHLETT LABORATORIES

Henry J. Hoffman has been appointed sales manager of the power tube division of Machlett Laboratories, Inc., Norwalk, Conn. He will also serve as administrative assistant to Miles Pennybacker, vice president.

Mr. Hoffman was formerly general manager of the special products division of Westinghouse. At present he is chairman of the electronics division of the National Electrical Manufacturers Association.

* * *

### MEISSNER TO MAKE PHONO-RECEIVERS

Combination receiver-record players with a unique tone control system will be made by Meissner Manufacturing Company, Mt. Carmel, Ill., in the postwar, according to G. V. Rockey, vice president.

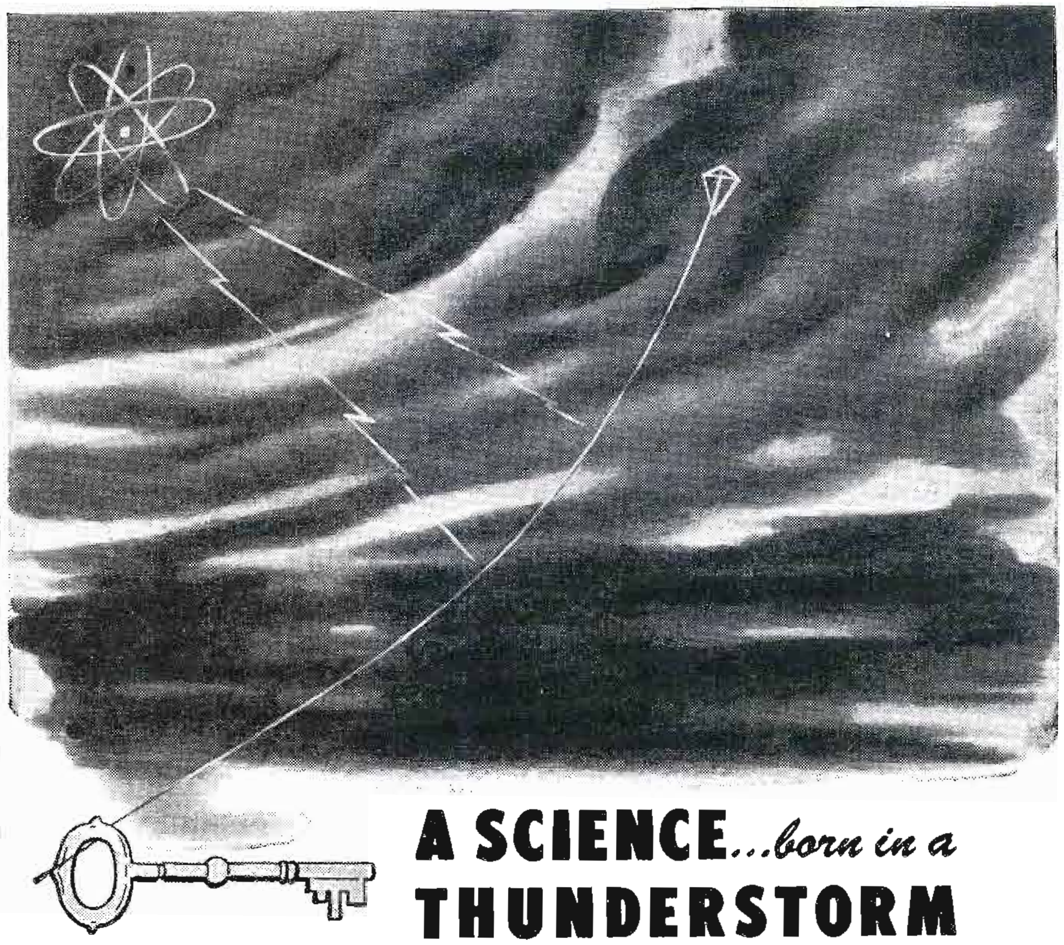
The new unit will also feature a new record changing device, that will play continuously for two hours or more. The record-changer is said to be capable of playing all records on one side, and then the other side. Or, it may be set to play both sides of each one before going on to the next. It is possible, also, according to Mr. Rockey, to reject any record in the series whether the machine is set to play in a straight run or on a work and turn basis.

* * *

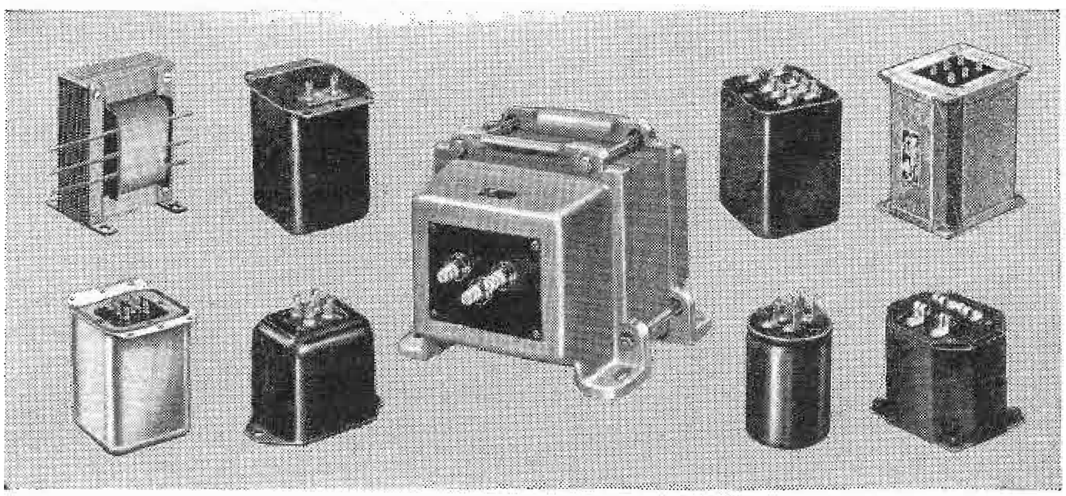
### UTC EMPLOYEES HONOR MITCHELL

At a recent meeting of employees and guests of the United Transformer Company, president I. Allen Mitchell was

(*Continued on page* 88)







## NEWS BRIEFS

(*Continued from page* 87)

awarded a plaque "in appreciation of (his) fine and cooperative spirit."

* * *

### B. & W. HEAVY-DUTY VARIABLE CONDENSERS CATALOG

A 4-page catalog, 75C, describing CX heavy duty condensers, has been issued by Barker & Williamson, 235 Fairfield Ave., Upper Darby, Pa.

The condensers feature built-in neutralization with short lead coil mounts.

* * *

### RADIO RECEPTOR AIRCRAFT COMMUNICATIONS BOOKLET

Radio's contribution to the safety of life and property on aircraft is described in a new booklet *Highways of the Air*, published by the Radio Receptor Company, 251 West 19th Street, N. Y. 11, N. Y.

In non-technical language, the function of aircraft communications equipment is told.

Among other topics explained is the airport traffic control system, as installed at LaGuardia Airport in New York, the new National Airport at Washington, D. C., and other modern air terminals. Various components including radio ranges and the several different types of markers are described and their uses discussed.


* * *

### DR. JOLLIFFE WRITES '43 RADIO INDUSTRY REVIEW

A review of the radio industry in 1943 has been prepared for the American Year Book by Dr. C. B. Jolliffe, chief engineer of the RCA Victor Division of Radio Corporation of America, Camden, New Jersey. Principal subjects discussed by Dr. Jolliffe include domestic broadcasting, international broadcasting, radio servicing, police and aviation radio, and electronics.

* * *

### SONORA RECORDS TO BE DISTRIBUTED NATIONALLY

Phonograph records will be distributed nationally by Sonora Radio & Television Corporation, Chicago. The facilities of WOR, Mutual Broadcasting System in New York City, will be used to produce all records.

* * *

### I. T. & T. LUNCHEON FOR VENEZUELAN PRESIDENT

A luncheon in honor of His Excellency, General Isaias Medina Angarita, President of Venezuela, and his official party, was given recently by International Telephone and Telegraph Corporation, with Colonel Sosthenes Behn, president of I. T. & T., as host.

* * *

### INSTRUMENT SPECIALTIES ISSUES BERYLLIUM DATA

A four-page folder discussing the present beryllium copper supply has been released by Instrument Specialties Company, Inc., Little Falls, New Jersey. The folder, entitled *Spiking A Rumor,* analyzes the present status and the future prospects of the beryllium copper supply.

* * *

### RCA PROMOTES UNDERHILL

Charles R. Underhill, Jr., RCA service representative in Pittsburgh for the past sixteen years, has been promoted to the home office staff of RCA's theater equipment section in Camden, New Jersey, where he is now in charge of the company's motion picture screen activities.

* * *

### F. LONG JOINS UNIVERSAL MICROPHONE

Floyd Long, radio engineer at the Oakland Airport for UAL, has joined the staff of the Universal Microphone Company, Inglewood, California, as technical engineer in the production control laboratory in charge of all company test equipment.

* * *

### PRECISION PAPER TUBE COMPANY EXPANDS

Additional manufacturing facilities have been acquired by Precision Paper Tube Company, 2035 West Charleston Street, Chicago 47, Illinois.

* * *

### EPEM HOLD CHICAGO CONFERENCE

Members of the Association of Electronic Parts and Equipment Manufacturers met recently at the Electric Club of Chicago. Paul V. Galvin, RMA president, was guest speaker, providing postwar forecasts. The meeting arrangements were made by Helen A. Staniland, vice president of Quam-Nichols Company, and Joe Thompson of Hallicrafters.

* * *

### SYLVANIA PRODUCTS OPEN NEW PLANT

Sylvania Electric Products, Inc., has established an additional manufacturing unit at Dover, New Hampshire.

* * *

### CECIL SLY ON EASTERN TOUR

Cecil L. Sly, vice president of the Universal Microphone Company, Inglewood, California, recently made a tour covering the Eastern area.

* * *

### ALLIED CONTROL BUILDING CHICAGO PLANT

Construction of a plant in Chicago has

(*Continued on page 90*)

## NEWS BRIEFS

(Continued from page 89)

been begun by Allied Control Company, New York.

* * *

**GLOBE-UNION AWARDED "E"**

The Army-Navy "E" has been awarded to Globe-Union, Inc., Milwaukee, Wisconsin.

* * *

**FOOTE NOW SALES COORDINATOR OF LITTELFUSE**

William A. Foote has been appointed sales coordinator of Littelfuse Incorporated, El Monte, California and Chicago, Illinois.

Mr. Foote was formerly president and general sales manager of the Wingfoote Petroleum Company.

W. E. Foote (left) and E. V. Sundt, president of Littelfuse, Inc.

* * *

**GROUP INSURANCE FOR DE JUR-AMSCO EMPLOYEES**

DeJur-Amsco Corporation of Shelton, Connecticut, has announced the introduction of group insurance covering every individual in their employ. Two types of protection are offered to the employees. These are group life insurance and hospitalization expense insurance, with the entire cost of the premiums paid for by the management.

* * *

**J. L. FOUCH WCEMA COMMITTEE CHAIRMAN**

James L. Fouch, president of Universal Microphone Company, Inglewood, California, has been appointed membership committee chairman for the recently formed West Coast Electronics Manufacturers Association.

* * *

**TUTTLE BECOMES RCA FIELD PROCUREMENT SPECIALIST**

James Tuttle, former manager of RCA

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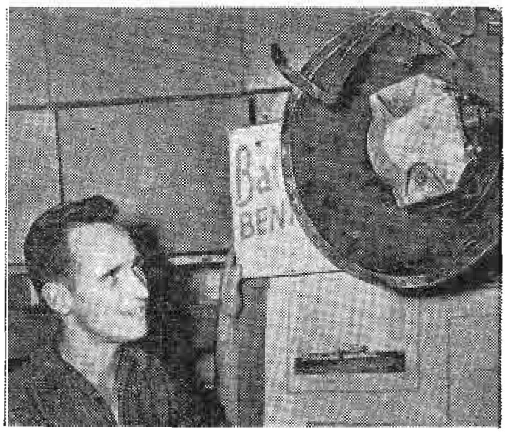
**BATTLIN' BENNY RETURNS**



Battlin' Benny, a shrapnel-torn loudspeaker which was aboard the U.S.S. Boise when the cruiser sank six Jap ships off the Solomons, is now holding down a war job at the RCA Victor plant, Indianapolis.

Victor Distributing Corporation of Chicago, has transferred to the general purchasing department of the RCA Victor Division as field procurement specialist, operating out of Chicago headquarters.

* * *

### WILLIAMS APPOINTED G.E. S-M

E. E. Williams has been appointed sales manager of the G. E. laboratory and measuring equipment section of the specialty division, and will have his headquarters at Schenectady. In his new capacity Mr. Williams will be responsible for the sale of laboratory, electronic measuring and test equipment, and will continue in charge of certain military radio subcontracts.

* * *

### HOEFLER HEADS ZENITH CHICAGO BRANCH

Ray L. Hoefler has been appointed general manager of Zenith Radio Distributing Corporation, to succeed R. E. McGreevy.

* * *

### SECOND WHITE STAR TO SIMPLEX

The Simplex Radio Division of Philco Corporation at Sandusky, Ohio, has just been awarded a second white star to add to its Army-Navy "E" flag.

* * *

### LIGHTCAP AND D'ALMAINE NOW AT N. A. PHILIPS

M. W. Lightcap has been appointed to the newly created position of distribution manager of the New York office of North American Philips Company, Inc., 100 East 42 Street. He will coordinate sales and distribution activities of the company's several divisions.

Harry D'Almaine will specialize in commercial control and analysis. He was formerly sales manager of Bodine Electric Company, Chicago, and more recently manager of business research for Irvington Varnish and Insulator Company.

* * *

### G.E. ELECTRONIC TUBE BULLETIN FOR INDUSTRY

A 4-page bulletin with a quick-selection chart of electronic tubes for industry is

(*Continued on page* 92)

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### SHIP LAUNCHING TELEVISED


G.E. workers at Schenectady, who built the electrical equipment of the new Queen of the Seas, the U.S.S. Missouri, witnessed the launching of the 45,000-ton battleship by television. The scenes were relayed by NBC's television station in New York to Schenectady.

## NEWS BRIEFS

*(Continued from page 91)*

being distributed by the tube division of G. E.

* * *

### CARRINGTON NOW ALTEC HEAD

George L. Carrington and Harry M. Bessey have been elected president and vice president respectively of Altec Service Corporation. Mr. Carrington succeeds the late L. W. Conrow.

In addition to his duties as president, Mr. Carrington will retain his position as general manager. He will also function as president of Altec Lansing Corporation.

Mr. Bessey assumes the post of vice president after serving as secretary-treasurer since 1937. He is a director of Altec companies, as well as an officer of Altec Lansing Corporation.

* * *

### GRAYSON AND ROBINSON IN NEW HAZELTINE POSTS

Fielding Robinson has been elected vice president of Hazeltine Electronics Corporation, 1775 Broadway, New York City. John D. Grayson was named treasurer.

Mr. Robinson has been with Hazeltine since 1941 as coordinator with various government agencies in Washington and other locations. Mr. Grayson also has been with Hazeltine since 1941 as comptroller.

* * *

### SYLVANIA PROMOTES BEN KIEVIT

Ben Kievit has become field engineer in the equipment sales department of Sylvania Electric Products, Inc., Emporium, Pennsylvania, for the New York and New England area. Mr. Kievit has been with the Sylvania corporation since 1930, when he joined the company as a research physicist. He is a senior member of the Institute of Radio Engineers, and a member of the Electronics Committee of that group. He has also served as technical editor of the *Sylvania Engineering News Letters* and the *Sylvania Technical Manual*, as well as assistant technical editor of *Sylvania News*.

Mr. Kievit's new headquarters will be 500 Fifth Avenue, New York.

* * *

### CANNON BATTERY CONNECTOR BULLETIN

A 24-page bulletin, describing battery connectors for aircraft, engines and general industrial uses, has just been issued

### ALLIED NATIONS WAR WORKERS

Three war workers, representing a different Asiatic race, at work bench at the Jefferson-Travis Radio Manufacturing Corporation, 245 East 23rd Street, New York. Left to right are Capt. Alvin Grauer, Industrial Service Branch, U. S. Army; Moy Guay Chuck, of Hoy Shan, China; Col. Charles W. Kerwood, U. S. Army Air Forces; Toshio Niniomiya, American-born Japanese, and Rama Chattopadhya, an American-Hindu.

by Cannon Electric Development Company, 3209 Humboldt Street, Los Angeles 31, Calif.

Application photos and condensed data sheets are included in the bulletin.

* * *

### GIBSON CONTACT CATALOG

A 16-page booklet describing electrical contact materials and their application has just been released by the Gibson Electric Company, 8350 Frankstown Avenue, Pittsburgh 21, Pa.

Analysis of silver alloy materials as used on springs, rivets and screws, etc., appear in this catalog.

* * *

### ELECTRONIC CONTROL BULLETIN

A 4-page leaflet describing rectifiers and electronic controls has just been issued by the Electron Equipment Corporation, Palm Springs, California. The bulletin provides data on low frequency converters, motor controls, phase converters, and cycle changing.

An additional bulletin covering speed controls has also been released by this company.

* * *

### DRY BATTERY MANUAL

A 48-page booklet entitled *The Inside Story of Dry Batteries* has been published by the National Carbon Company, 30 East 42 Street, New York 17, N. Y.

There are seven chapters in this booklet covering the evolution of the dry battery and the development and design of the cylindrical and flat-type batteries. Electrical and chemical data analyzing dry battery operation are presented, together with diagrams and cut-away illustrations. The popular air-cell battery is also explained.

* * *

### DI-ACRO CATALOG

A 44-page catalog describing metal duplicating processes without dies has been issued by the O'Neil-Irwin Manufacturing Company, Minneapolis 15, Minnesota.

Data in this new catalog covers Di-Acro benders, shears and brakes. Examples of parts produced by these devices are illustrated and described.

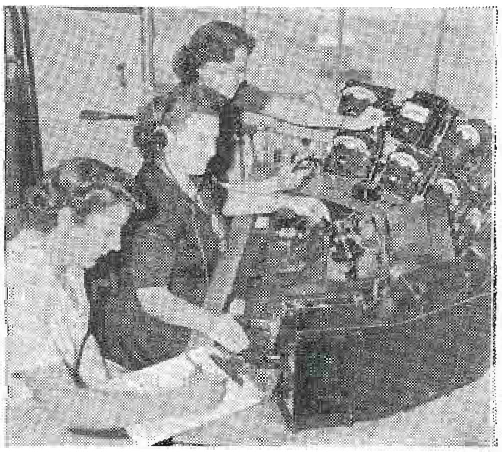
* * *

### GRAMMES WINS "E"

L. F. Grammes & Sons., Inc., Allentown, Pa., were recently awarded the Army-Navy "E."

(*Continued on page* 99)

### TOP APTITUDE GIRLS NOW ENGINEERS



**Dorothy Nebraska, engineering assistant, center, at her meter desk, aided by two new girls in unusual test department just established by Sylvania Electric Products, Inc., Emporium, Pennsylvania.**

## F-M/A-M DETECTOR

*(Continued from page 27)*

The voltage across the inductance L is then

$$E_k = L\frac{di}{dt} \qquad (8)$$

$$= LA\,(\omega + \alpha\, a \cos \alpha\, t)\cos(\omega t + a \sin \alpha t)$$

$$= LA\,(\omega + \omega\, m \cos \alpha\, t)\cos(\omega t + a \sin \alpha t)$$

$$= LA\,\omega\,(1 + m \cos \alpha\, t)\cos(\omega t + a \sin \alpha t) \qquad (9)$$

This is a wave with an amplitude modulated envelope $(1 + m \cos \alpha\, t)$ to which the diode can respond.

From equation *2* and *9* it can be seen that an amplitude modulated wave will be introduced into the input. However the d-c potentials on the tube have been so adjusted that it does not respond to amplitude variations. Thus this may be neglected.

It has been assumed that $Z_k$ was equal to $X_L$. This disregards the effect of the resistance of the coil, capacitance from cathode to ground, and stray and coil capacitance. Actually, of course, instead of having a straight line for the impedance as in Figure 6, the situation in Figure 7 may more nearly apply. There are portions of the curve that approximate a straight line, but for wide band f-m it may be necessary to substitute for the cathode coil, a network which has a linear impedance versus frequency characteristic. The design of the cathode impedance depends upon the bandwidth and permissible distortion. The cathode coil alone seems adequate in many instances, particularly if its value is selected carefully. Otherwise combinations of series and parallel resonance may be made to adjust the linearity somewhat. Also by this means, slope may be adjusted and greater slope means greater audio output.

For communication work, utilizing low deviation ratios, a narrower band of frequencies is used and distortion is of no particular consequence. Therefore a part of the curve that has the greatest slope should be used, thereby obtaining maximum audio output.

In the case of broadcast reception, the most advantageous point for operation would appear to be somewhat higher in frequency than resonance, as there is a straight line portion of appreciable length.

Using this circuit, shown completely in Figure 8, we note that the functions of detection for frequency modulation are completed by a tube complement and associated equipment comparable to amplitude modulation.

The complete detector, suitable for either frequency modulation or amplitude modulation consists of one tube and is adaptable for either, by merely changing the potentials on the triode section. This is a change of d-c potential and is accomplished without any switching of r-f or audio voltages. Wiring and parts necessary are reduced to a minimum. Thus considerable economy is effected. In addition, possibilities for unwanted interaction are decreased.

Most a-m/f-m receivers use a separate detector for amplitude modulation. This arrangement can accomplish as much as three tubes with some arrangements. If desired, of course, part of the tube and circuit economy may be utilized to provide another limiter tube and obtain benefits thereby derived by cascade limiting.

Automatic volume control voltage is provided by the extra diode in the a-m position. When the switch is thrown to the f-m position, limiting takes place. A low value of bias voltage, which is fixed in value, is obtained, since variations in rectified carrier are prevented. This provides a fixed bias on the radio frequency amplifier tubes, insuring maximum carrier input to the limiter for best action. This change in characteristics takes place without any further switching, the proper result appearing automatically.

An experimental receiver with this detector circuit provided satsfactory results on both frequency modulated and amplitude modulated signals. Additional studies of the characteristics of the system were made in the following way. The detector was removed from the chassis. A signal generator was used to supply various frequencies to the input of the triode section while a vacuum tube voltmeter provided the voltage across the diode load resistor. The results obtained are shown in Figure 9. The receiver used an intermediate frequency of about 1.6 megacycles, thus utilizing the straightest part of the curve.

The author wishes to thank Prof. W. S. Davis of Fenn College for the use of laboratory facilities to measure the characteristics of this combination detector.

[1]The negative sign comes from the fact that there is a phase shift of 180° through the tube.

[2]F. C. Everett, *A New Detector*, COMMUNICATIONS; September, 1942.

•

**PAPER PACKS A WAR PUNCH**
**FIGHT WASTE!**

•

## QUARTZ

(*Continued from page 66*)

crystal surface. Therefore, we may calculate the dimensions of a resonant air gap for any frequency as follows: Assuming air temperature to be plus 20° C, the velocity, $v$, of the supersonic pulse will be 1130' per second. Let us then designate the dimensions of the gap as $g$ and the frequency of oscillation of the crystal as $f$.

For resonance $g = \frac{1}{2}\lambda$

but
$$\lambda = \frac{v}{f}$$

$$\therefore g = \frac{\lambda}{2} = \frac{v}{2f}$$

For example at 7.0 mc

$$g = \frac{1130 \text{ ft./sec.} \times 12 \text{ in./ft.}}{2 \times 7 \times 10^6 \text{ cycles/sec.}}$$
$$= .0009 +''$$

Air gap resonance effects are not too noticeable with thickness-shear oscillators. There is a small component of motion in a direction perpendicular to the surfaces of the crystal but the effect is small and generally not troublesome.

One of the most important departments in a crystal manufacturing plant is the *reclamation department*. Here, the component parts of the final crystal assemblies are salvaged from rejected units. If the crystal oscillator plate was rejected because of an activity dip, the edges are ground. It is wise to notify the person who regrinds the edges of the nature of the activity dip and where it occurred. Sharp dips occurring at the high temperature end of the range may be corrected with slight edging. Mechanical activity dips may be corrected by the replacement of electrodes or the pressure spring. Activity failures which occur near 0° C and which do not oscillate at all below zero, probably have too much moisture within the holder itself. At zero, the water vapor precipitates and freezes and may completely damp oscillation. If an activity reject is reworked and fails for the same reason, the second time, the crystal must be reexamined for surface contour, twinning, and other physical flaws. It should be possible for a crystal production department to maintain an activity reject figure which is quite low especially if predimensioning techniques are applicable.

Frequency rejects may be of two kinds: (*1*)—If the crystal is cut off angle beyond allowable tolerances, the temperature coefficient curve may be far out of symmetry and the crystal will exceed its low frequency side tolerance. (2)—If the crystal is finished to a frequency which is too close to the positive side tolerance, it may drift beyond tolerance at the turning point.

The first type should be set aside for future use where specific conditions of operation will make that particular angle of cut of oscillator plate usable. The second type may be repaired, if the angle of cut is proper, by increasing the shunt capacity and thus lowering the resonant frequency. If the gaps are too small for this remedial measure, the crystal must be further lapped to a next higher frequency.

With the precision sawing equipment and orientation equipment now available, it is possible to keep off angle cuts below 1%. Considering the small errors which may cause trouble and the narrow tolerances allowed, such a figure is the result of careful supervision and careful upkeep of all manufacturing processes and machinery. All component parts should be easily salvaged and completely reused unless such component parts are the cause of failure.

Electrodes are generally manufactured of non-corrosive metal and must be a precision manufactured product. The four corners should be flat and in the same plane. Methods have been developed which permit the lapping and polishing of electrode corners so that an optical flat examination shows less than two fringes deviation from flat. Polishing the corners may decrease the friction between electrode and crystal surface of a thickness-shear oscillator plate sufficiently to increase the activity several percent.

All butt ends and test slices are saved for future use. After the war, there should be a great market for such oscillator plates which do not have to meet the most rigorous specifications of the present time.

Heat has been used recently in quartz manufacture in an interesting way. Heat treatments have effected untwinning of twinned quartz. It may be possible at some future date to utilize much of the scrap wafer stock cut by every manufacturer if such an untwinning procedure is easily controlled. The general idea behind this technique is that at temperatures above 573° C quartz is no longer piezoelectric because of a shift of atomic structure from one of trigonal to hexagonal symmetry. If the quartz is cooled slowly and under the proper conditions it may be possible, after having thus rendered it inactive piezoelectrically, to reorient completely the atomic spirals so that the structure is homogeneous.

The postwar possibilities of quartz

(*Continued on page* 98)

## QUARTZ

(*Continued from page 97*)

oscillating and resonating plates are enormous. They will probably be used for automatic tuning devices for home radios, controlling simultaneous channels of voice transmission over u-h-f carriers, and many other applications requiring careful control.

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**Bibliography**

*X-Rays and Crystal Structure;* W. H. & W. L. Bragg

*Crystallography and Practical Crystal Measurements;* A. E. H. Tutton; Vols. 1 and 2

*A Study of Crystal Structure and Its Application;* Wheeler P. Davey

*The Physics of Crystals;* Abram R. Joffe

*The Nature, Origin and Interpretation of Etch Figures of Crystals;* A. P. Honess

*Properties of Silica;* R. B. Sosman

*Modes of Vibration in Piezo-Electric Crystals;* A. Crossley, IRE Proceedings; April 1928

*Piezo-Electric Resonator in High-Frequency Oscillation Circuits;* Yasusi Watanabe, IRE Proceedings; May 1930

*A Determination of Some of the Properties of the Piezo-Electric Quartz Resonator;* Karl S. Van Dyke, IRE Proceedings; April 1935

*A Simplified Circuit for Frequency Sub-Standards Employing a New Type of Low-Frequency Zero-Temperature-Coefficient Quartz Crystal;* S. C. Hight and G. W. Willard, IRE Proceedings; May 1937

*A New Quartz Crystal Plate, Designated the GT;* W. P. Mason, IRE Proceedings; May 1940

*A New Direct Crystal-Controlled Oscillator for Ultra Short-Wave Frequencies;* W. P. Mason and I. E. Fair, IRE Proceedings; October 1942.

*Low Temperature Coefficient Quartz Crystals;* W. P. Mason, The Bell System Technical Journal; January 1940

*Quartz Crystal Applications;* W. P. Mason, The Bell System Technical Journal; July 1943

*Methods for Specifying Quartz Crystal Orientation and Their Determination by Optical Means;* W. L. Bond, The Bell System Technical Journal; July 1943

*Use of X-Rays for Determining the Orientation of Quartz Crystals;* W. L. Bond and E. J. Armstrong, The Bell System Technical Journal; October 1943

*Raw Quartz, Its Imperfections and Inspection;* G. W. Willard, The Bell System Technical Journal; October 1943

*Small Temperature Coefficent of Frequency of Quartz Plates;* Peter Modrak, The Wireless Engineer; January 1939

*Longitudinal Shear and Transverse Modes of Vibration in Quartz and Tourmaline;* Harold Osterberg and John W. Cookson, Physics Magazine; July 1935

*The Piezo-Electric Resonator and The Effect of Electrode Spacing Upon Frequency;* W. G. Cady, Physics Magazine; July 1936

## NEWS BRIEFS

(*Continued from page 93*)

### W. E. BOOKLET ON WAR COMMUNICATIONS

A 44-page booklet in picture magazine form, entitled *Battle Talk*, highlighting the story of communications production since the year before Pearl Harbor, has been issued by Western Electric. It is being distributed to more than 82,000 employees.

* * *

### G.E. TUBE BULLETINS

Revised technical descriptive bulletins on the G. E. GL-207, 846, 860, 861, 1616, 8010 A-R and 8020, have just been issued. Revised installation and operation bulletins on the GL-811, 810, 806, 803, 836 and 8010 A-R have also been issued by G. E.

* * *

### SYLVANIA DATA ON 28D7 AS POWER SUPPLY SOURCE

Additional data on the performance of Sylvania 28D7 tube used as a power oscillator d-c source with the battery supply voltage varying over wide limits are given in Sylvania News Letter 78.

* * *

### KEMP NOW WARWICK MANUFACTURING S-M

Reau Kemp was recently appointed sales director of Warwick Manufacturing Corporation, 4640 West Harrison Street, Chicago.

Warwick is producer of Clarion radios and electronic equipment.

Mr. Kemp comes to Warwick from a term of service with the War Production Board in Washington.

•

### VIA CARRIER CURRENT

(*Courtesy Westinghouse*)

A recent carrier current installation for speech transmission.

## IRE REPORT

(*Continued from page 31*)

said that three functions must be performed. That is, we must first obtain gain. Then we must have a device to produce a change of phase shift with a change of frequency, *a filter*. And lastly, some amplitude-limiting device is also necessary, he pointed out. This last point was stressed. He said that this function is often left to the tube itself. However, he pointed out, all useful oscillators show considerable excess gain if measured at a low enough level. We must account for this excess gain, he said, with a limiter so that a finite constant output can be reached.

Circuits in which these three functions are performed by separate elements are relatively simple to analyze, pointed out Mr. Edson. However, he said, there are many useful circuits that combine two of the functions in such a way that the analysis is more complicated. As examples he cited the Hartley and Meacham circuits.

Limiters were classified by Mr. Edson into four groups. They included thermal devices such as carbon and tungsten lamps; varistors such as copper oxide thyrite and some electronic diodes; tubes which reduce their gain with simple overload with an increase of current through them; and tubes which reduce their gain by virtue of a bias developed as a result of oscillation.

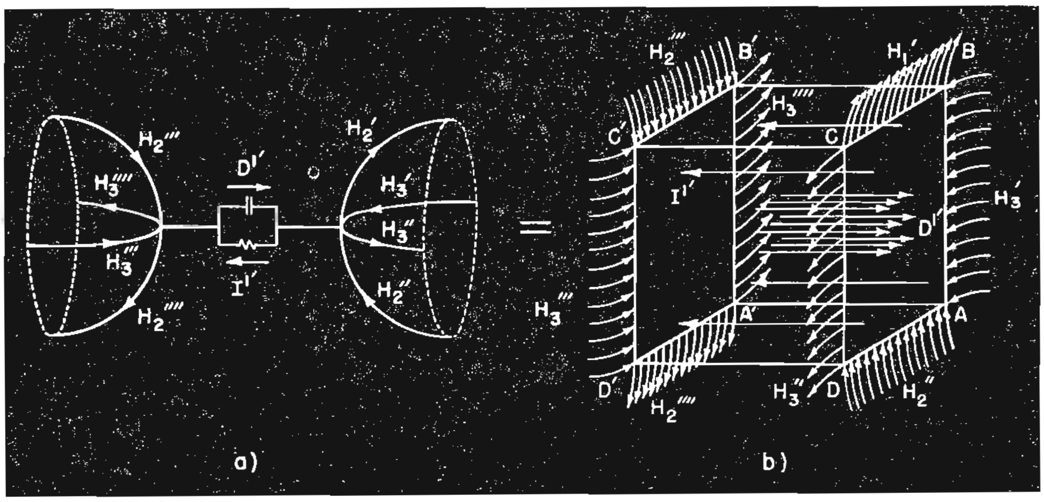
A lamp stabilized oscillator was used by Mr. Edson in his analysis. By his method it is possible to determine when interruptions will occur and what circuit change will eliminate them. Mr. Edson pointed out that the low frequency disturbances which may appear in oscillators of all sorts usually is a low frequency interruption of the desired oscillation.

He also presented a sample design of a bias-controlled oscillator to show how the analysis may be used in design work. Presented too was a computation of the stability condition for a Meacham oscillator. Design information for a self-modulating oscillator was also presented to illustrate how it is possible to introduce and control modulation.

### *Transient Problem Analysis*

A METHOD for solving transient or steady state electromagnetic field problems using equivalent circuits was analyzed in a trio of pa-

Figure 13
Proof of Ampere's law as projected in Gabriel Kron's paper.



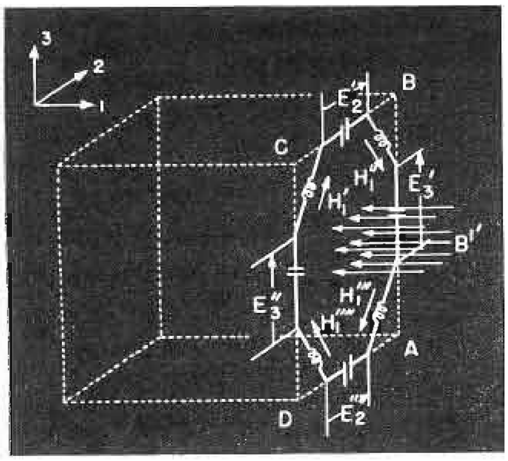



Figure 14
Proof of Faraday's law as discussed in Dr. Kron's paper on "The Equivalent Circuit of the Field Equations of Maxwell—I."

pers by General Electric engineers. The discussion, conducted by J. F. McAllister, covered "Equivalent Circuit of the Field Equations of Maxwell—I" by Gabriel Kron; "A New Approach to the Solution of High Frequency Field Problems" by J. R. Whinnery and Simon Ramo; and "A-C Network Analyzer Studies of Electromagnetic Cavity Resonators" by J. R. Whinnery, C. Concordia, W. Ridgway, and Gabriel Kron.

With the aid of a network analyzer, it is possible to obtain field distributions in the neighborhood of odd shaped bodies such as antennaes, cavity resonators, and waveguide discontinuities, explained Mr. McAllister.

In Dr. Kron's paper an equivalent circuit representing the field equations of Maxwell for an electromagnetic field containing conductors and bound charges was shown. The circuits were developed for all curvilinear orthogonal reference planes to provide a solution of three dimensional problems with axial and other symmetry by the use of only a two-dimensional network. According to Dr. Kron, one set of two dimensional networks, the transmission line type, requires only resistances, inductances and capacitors, while its dual set requires also ideal transformers in series with the inductive coils. In the transmission line type of networks, according to Dr. Kron, the dual ideal transformers consist of impedanceless conductors.

The Whinnery-Ramo paper of this group discussed the equivalent circuit technique for solving high frequency field problems in a preliminary way so as to speed its evaluation. According to the authors of this paper, the equivalent circuit approach may have important and immediate usefulness. This is based on the results of a preliminary experimental investigation. They reported that in many field problems it may be possible to obtain useful approximate solutions by measur-

(*Continued on page* 102)

# IRE MEETING REPORT

(*Continued from page* 101)

ing voltages and currents in a proper electrical network whose boundaries correspond to those of the field problem.

This discussion, by the way, centered around the possible application of an equivalent circuit suggested by Dr. Kron to the solution of high frequency field problems.

The concluding paper of Whinnery, Concordia, Ridgway and Kron, discussed by Mr. McAllister, covered the results of a study made on the a-c network analyzer to investigate an equivalent circuit of the field equations of Maxwell for charge-free space. Three configurations were studied. These were a rectangular two dimensional cavity, a cylindrical cavity and an L-shaped two-dimensional cavity.

The authors pointed out that in these studies the number of units ranged from about seven to twelve per wavelength. For certain quantities, they said, accuracy was consistently better than 5%, but for other quantities, particularly in the vicinity of cut-offs or resonances, agreement was much poorer. The required subdivision into units, they pointed out, was affected by the size of the discontinuities as well as by the wavelength.

### The FCC

FOUR interesting papers covering the engineering work of the FCC were presented by E. K. Jett, chief engineer, C. P. Adair, assistant chief engineer, W. N. Krebs, chief of the safety and special services division, and P. F. Siling, chief of the international division.

Mr. Jett covered the general activities of the engineering division, and outlined some of the problems which require their attention. He discussed postwar problems too. He pointed out, for instance, that after the war we will have to have a much larger usable spectrum. The apparent roominess above the high frequency channels, such as 300 mc, ceases to look so encouraging, he pointed out, when we consider the vast number of channels that will be required for half a million airplanes by 1950, a four-ocean Navy, a huge Army communication system, police radio, harbor radio, f-m, facsimile, etc. And, he explained, when you consider the demands of television which require a channel of at least 6,000 kc wide, or wide enough for a hundred or more standard width communication channels, the picture becomes even more discouraging. The problem of finding enough channels to satisfy everybody is quite complex, he explained. However, he said, if we do a reasonably good planning job now, there will be room for at least the minimum frequency requirements of all legitimate radio services.

Mr. Jett also discussed relay channels in the postwar program. He said that he understood that considerable advancement had been made since Pearl Harbor in developing frequencies above 300 mc for the distribution of network programs. He also pointed out that the same networks may just as easily carry telephone and telegraph messages and compete with the services now furnished by the wire carriers. Questions of this nature, of course, may require ammendments to the Communications Act, he explained.

He posed some very interesting questions concerning the use of such u-h-f nationwide networks. These included... Who should be granted the privilege of operating this system? Should it be competitive with the telephone and telegraph services which now operate as monopolies in their respective fields? Should there be competitive radio networks, thereby necessitating a forest of towers along the same route? Should the company or companies operating the radio network also be permitted to operate terminal facilities at the subscribers' offices? Should the chain broadcasting companies be permitted to own and operate their own radio networks?

"These are but a few of the questions which will confront the Commission when, as and if materials and manpower again become available for the production of civilian equipment," said Mr. Jett.

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## RADIO RANGE BEACONS

(*Continued from page* 48)

rough weather the danger is obviously greater.

When the pilot is on a leg of an *SRA* (or *SMRA*) range he receives, as he would from an *MRL* station, either the steady tone or individual quadrant signals interrupted by the call. *But* (and this is the important thing), when weather broadcasts are made by the range stations, he hears them *at the same time* as the regular range signals, which are not cut off as in the case of the *MRL* transmitter.

The pilot who has his switch in the proper position hears the range signals in one earphone and the weather information in the other. The range signals continue to be interrupted at regular intervals by the station call letters. In larger aircraft, where the pilot sometimes listens constantly to the range while the co-pilot records the weather or voice broadcasts, the receiver is arranged so that one set of headphones can be connected to the range and another to the voice broadcasts.

The distance a radio range can be heard depends on the power output and type of station, the time of day, and the terrain controlled by its legs. At nighttime in mountainous regions the useful range of an *MRL* station may not exceed twenty or thirty miles, while over water the same type of station may put out signals audible up to two- and three-hundred miles. In relatively flat territory the normal range of an *SRA* station is from one-hundred and fifty to two-hundred miles.

Radio range beacons have been in use in the U.S. for over fifteen years. The more than five hundred stations operated in the continental U.S. by the AACS and the CAA and the large number of new stations activated each month here and abroad by the AACS are strong evidence of their effectiveness and generally satisfactory performance. The most serious adverse criticism that can be leveled against them is the fact that in mountainous regions they develop multiple courses. In this country these are frequently met with in the Alleghenies, the Rockies, and the ranges of the West Coast. So far, the only means of checking the effect of these reflections that disturb the range pattern is a system of monitoring ranges wherever possible and charting the multiple courses so that pilots flying such routes will know of their existence.

## SIGNS IN VACUUM TUBES

(*Continued from page* 38)

| | |
|---|---|
| $e_g$ | Instantaneous grid voltage |
| $e_p$ | Instantaneous plate voltage |
| $e_L$ | Instantaneous voltage drop across tube load |
| $(e_g)_c$ | Instantaneous grid control voltage |
| $I_p$ | Complex plate current, rms, of complex peak value $I_{pm}$ |
| $\lvert I_p \rvert$ | Plate current, rms, of peak value $\lvert I_{pm} \rvert$ |
| $E_g$ | Complex grid voltage, rms |
| $E_p$ | Complex plate voltage, rms |
| $E_L$ | Complex voltage across load, $E_L = -E_p$, rms |
| $E'_L$ | Complex voltage across output terminals, rms |
| $(E_g)_c$ | Complex grid control voltage, rms |

(*All deviations measured from average values*)

•

## IMPEDANCE TRANSFORMATION

(*Continued from page* 56)

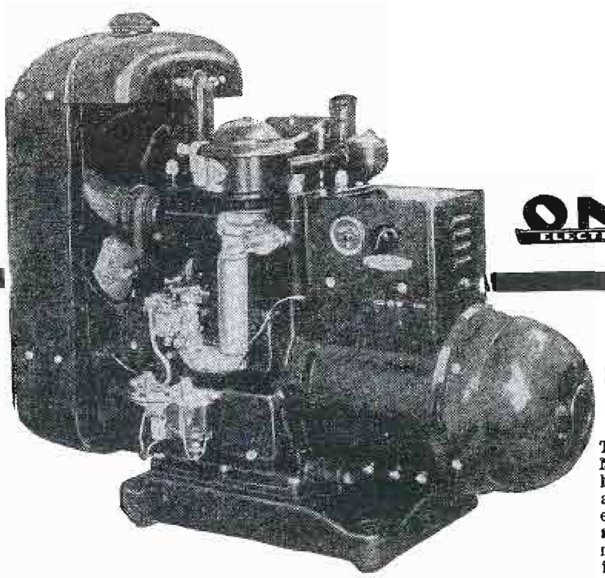
changed. We thus see that only *constant R* lines and *constant G* lines may be followed by the *Z* point in moving from $Z_r$ to $Z_t$. This would also apply to any other point chosen to represent impedance as, for example, the *Y* point.

There is one *constant R* and one *constant G* line through each of the *end points,* $Z_r$ and $Z_t$, or four lines altogether: two straight lines and two circles. Three possibilities are listed in Figure 5, depending on the relative values of $Z_r$ and $Z_t$. As explained in Figure 5, there are always two possible solutions, sometimes four. When four alternatives are possible, two of them call for the use of condensers only, (or coils only).

Figure 5 also presents a numerical example. A handy tabulation for determining what element addition corresponds to a given displacement of the impedance point is also given.

In the concluding installment will appear a discussion of impedance transformation obtained by means of u-h-f transmission lines.

*(A fuller treatment of this subject will appear in a forthcoming book by Mr. Selgin on* **Steady State Transmission** *to be published by Prentice-Hall.)*



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# "R-9" Quartz Crystals
*for*
## Frequency Control
*and*
## Special Applications
*are*
## Accurate, and Dependable

We are equipped to handle any type or size order. May we quote you on your future requirements? Immediate delivery.

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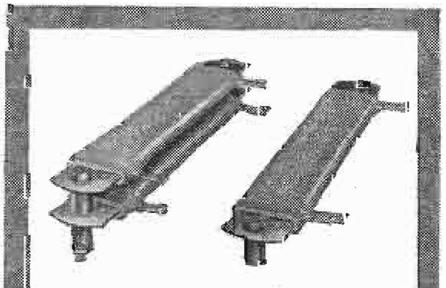
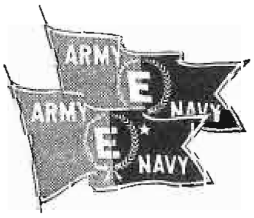
# Does Your Product Require More Compact Resistors?

The war has proven the importance of compactness in radio, electronic and electrical equipment. Unquestionably the dimensions of many post-war products will reflect the studies that have been made to conserve space. More compact components developed for the war will find great demand for peace-time users.

The Ward Leonard Strip Type Resistor is a typical example. Its flat section permits installation in places where there is not room for a round section resistor of the same value. Other regular Ward Leonard Resistors are available for special purposes.



Strip Resistors may be mounted singly or mounted in any multiples.




The Ward Leonard Resistor Catalog shows resistors of various types, terminals, mountings, enclosures, and resistance values. Send for it.

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**WARD LEONARD ELECTRIC COMPANY**
**75 SOUTH STREET, MOUNT VERNON, N. Y.**

## THE INDUSTRY OFFERS . . . —

(*Continued from page* 85)

an eight-hour portable, a one-to-eight hour stationary unit, and a small unit which records for up to one hour.

* * *

### REINER WIDE-RANGE OSCILLOSCOPE

A 5″ oscilloscope, model 556, equipped with a direct reading voltmeter for measuring the input signal, is now being made by Reiner Electronics Co., 152 West 25th Street, N. Y. 1, N. Y.

The sweep generator is said to have a frequency range of 1000 kc., 20 cycles to 1 mc. The horizontal amplifier as well as the vertical amplifier is said to be practically flat to 2 megacycles; Z axis amplifier is said to be useful up to 6 megacycles, permiting blanking and marking.

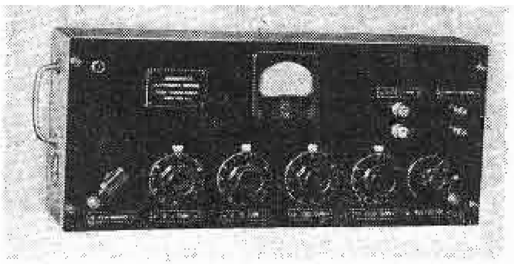
* * *

### TECH LAB MICROHMMETER

A completely a-c operated instrument capable of measuring from .0001 ohm to one megohm has been designed by Tech Laboratories, 7 Lincoln Street, Jersey City 7, N. J.

The low current at the terminals of the instrument known as type G-710 microhmmeter, makes it possible to measure contact resistance in relays, switches, joints, bondings, etc., without changing the actual conditions of contact by heat or welding effect. No current terminals are said to be required as used in the Kelvin bridge. High current effect may be studied, however, by applying up to 5 amperes, in series with the resistance under test. This will not change the readings except for the internal resistance of the d-c source (0-1 ohm range).

Sensitivity is said to be variable from zero to one part in 10,000. A .5-0-.5 ma d-c galvanometer is used as a null indicator. There is said to be sufficient d-c output to drive a recorder or sensitive relay. Size 18½″ x 8½″ x 6″.



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### A-M-P PRE-INSULATED SOLDERLESS TERMINALS

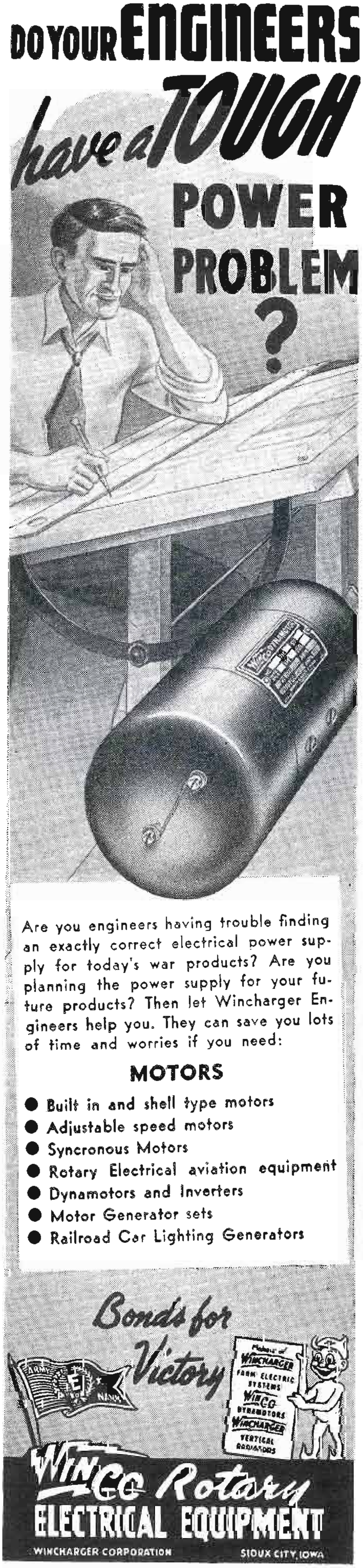
Pre-insulated terminals with the insulation permanently bonded to the copper of the terminal have been produced by Aircraft-Marine Products Inc., 1591F North Fourth Street, Harrisburg, Pa.

These terminals are said to require only one operation, crimping the terminal on the wire with an A-M-P installation die. The pre-insulation is said to take the exact contour of the crimp without distortion, cracking, or drying out in use.

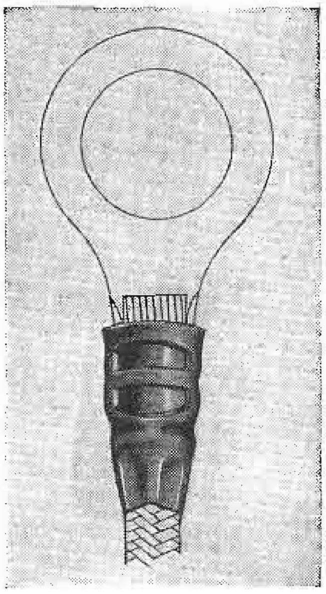
For identification of terminals and matching dies each of two sizes are








marked with distinctive colors; red for terminals and dies for wire sizes 22 to 18, and blue for wire sizes 16 to 14.



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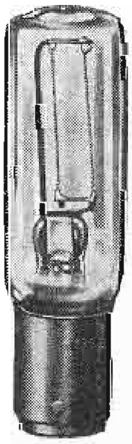
**MIDGET AMPERITE REGULATOR**

Compact automatic regulators designated as the T-6 are announced by the Amperite Company, 561 Broadway, N. Y. 12, N. Y.

An increase in voltage of approximately 250% with a 10% change in current through it, is said to be available. This regulation is obtained by the use of an iron filament hermetically sealed in a hydrogen atmosphere. A standard two-contact auto base is used.



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**AMERTYPE FILM RECORDER**

An acetate film tape recording unit, the Recordgraph, has been announced by the Amertype Recordgraph Corporation, 333 West 52 Street, New York 19, N. Y., a subsidiary of American Type Founders.

The unit is said to be capable of providing 5 hours of permanent recording, using 35mm film.

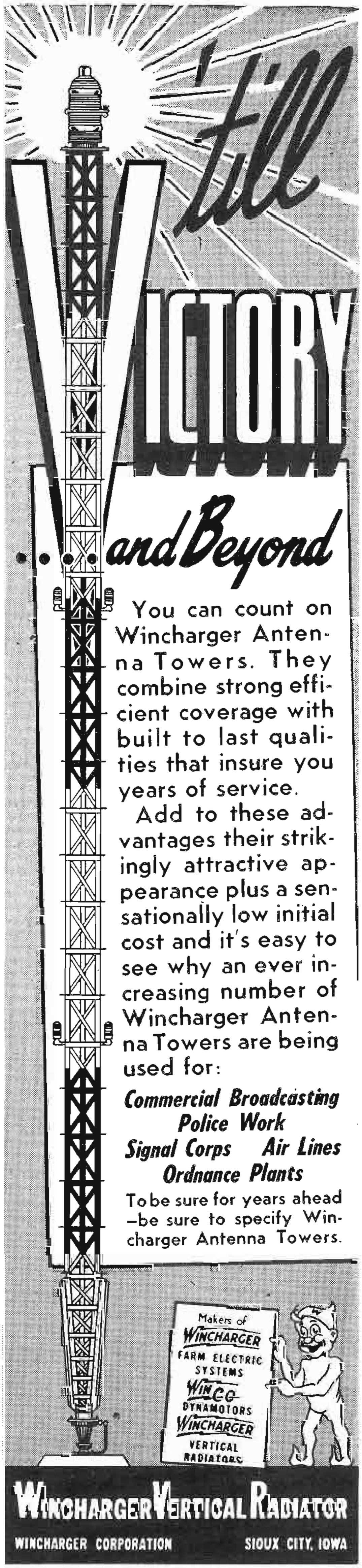
* * *

**RCP PRODUCTION MULTITESTER**

An electronic multitester for speed production testing is now available from Radio City Products, 125 West 26th St., N. Y. 1, N. Y.

Known as the 663A multitester it is said to provide 27 vacuum tube operated ranges; 13 a-c and d-c voltage scales, measuring from a fraction of a volt to 6,000 volts. High voltage test leads; r.f. lead; signal tracing probe; resistance and capacity lead, and a voltage regulator VR 105-30 are also included.

Size is 9¾" x 10½" x 6½"; weight is 7¾ pounds.



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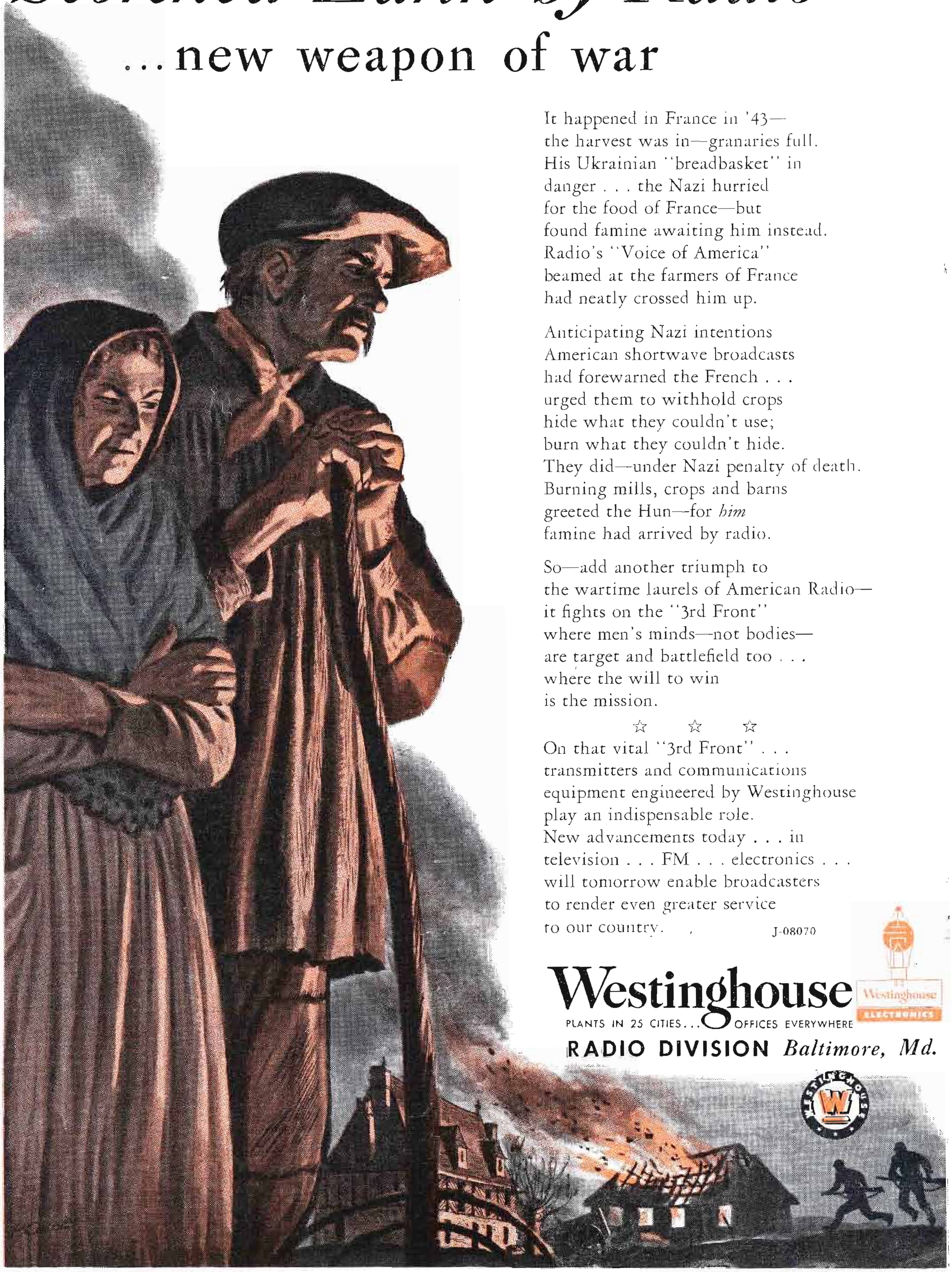
COMMUNICATIONS—FEBRUARY, 1944

# "Scorched Earth" by Radio

## ... new weapon of war



It happened in France in '43—
the harvest was in—granaries full.
His Ukrainian "breadbasket" in
danger . . . the Nazi hurried
for the food of France—but
found famine awaiting him instead.
Radio's "Voice of America"
beamed at the farmers of France
had neatly crossed him up.

Anticipating Nazi intentions
American shortwave broadcasts
had forewarned the French . . .
urged them to withhold crops
hide what they couldn't use;
burn what they couldn't hide.
They did—under Nazi penalty of death.
Burning mills, crops and barns
greeted the Hun—for *him*
famine had arrived by radio.

So—add another triumph to
the wartime laurels of American Radio—
it fights on the "3rd Front"
where men's minds—not bodies—
are target and battlefield too . . .
where the will to win
is the mission.

☆ ☆ ☆

On that vital "3rd Front" . . .
transmitters and communications
equipment engineered by Westinghouse
play an indispensable role.
New advancements today . . . in
television . . . FM . . . electronics . . .
will tomorrow enable broadcasters
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