A good idea for
TELEVISION engineers

... Use Flexible Shafts
to simplify the controls

The principle of using flexible shafts for "Coupling" tuning knobs to their respective elements in the circuit, which has proved effective in radio equipment, is just as sound and desirable for TELEVISION transmitters and receivers.

The RCA Radio Broadcast Transmitter illustrated, shows clearly how this principle solves a number of vital design problems—how the use of flexible shafts permits unrestricted freedom in placing tuning knobs and circuit elements in the most advantageous positions to satisfy all four of the following important requirements:

(1) Circuit efficiency
(2) Easy and Economical Assembly
(3) Servicing Convenience
(4) Operating Facility for the User.

ENGINEERING AID

Our full cooperation is offered to TELEVISION designers for working out the details of applying "Coupling" shafts to specific equipment. This cooperation involves no obligation—to consult us freely. As a preliminary, send for ENGINEERING BULLETIN 38 which tells all about S. S. WHITE flexible shafts for "Coupling." A request on your business letterhead brings you a free copy. Write for it—today.

S. S. WHITE
The S. S. White Dental Mfg. Co.
INDUSTRIAL DIVISION
Department E, 10 East 40th St., New York, N. Y.

July 1939 — ELECTRONICS
CONTENTS—JULY, 1939

ORTHICON DUCK ......................................................... Cover

This toy duck acted as a patient subject in the research laboratories of RCA Radiotron, Harrison, during the development of the new Orthiconoscope, a greatly improved form of the iconoscope (see page 11). The picture is a standard 441-line image picked up on the new tube and reproduced on a conventional picture tube.

POWER IN SOUND ..................................................... Frontispiece

Four 100-watt loudspeakers, shown on test during the construction of the New York World's Fair, capable of covering an area one-half mile deep.

THE ORTHICON .......................................................... 11

An improved form of the iconoscope makes use of low-velocity scanning electrons and obtains thereby greater efficiency, freedom from spurious signals, and linear output.

APPLICATION OF COPPER-OXIDE RECTIFIERS, by Leo L. Beranek . 15

Use of small CuO rectifiers in conjunction with audio frequencies, for metering, and in modulation applications.

PHOTOGRAPHING C-R TUBE SCREEN TRACES, by T. A. Rogers and B. L. Robertson . 19

Relation of screen characteristics and "writing speed" to lens aperture and exposure for various emulsions and developers.

A HIGH-QUALITY RADIO BROADCAST RECEIVER ................. 20

Details of the r-f, i-f detector, and audio sections of a receiver designed by Lincoln Walsh, of high frequency-response and distortion performance.

A PROGRAM FAILURE ALARM, by H. A. Chinn and R. B. Moe . 24

A program rectifier and relay arrangement, with adjustable time delay, for notifying broadcast station operators when an audio circuit fails.

SOUND, WATER, AND FIRE ......................................... 26

A description of one of the most elaborate sound systems ever installed, at the Lagoon of Nations at the New York World’s Fair. Twenty-seven inch speakers, and a total of two kilowatts of audio power.

A COMPACT REMOTE AMPLIFIER, by R. S. Duncan . 28

A small, portable remote amplifier of high quality, of special interest to broadcast station operators who “build their own.”

INSTALLATION OF COAXIAL TRANSMISSION LINES, PART I, by J. B. Epperson . 30

Details of installation procedure for broadcast transmission lines, methods of inserting solder couplings, etc. First of two parts.

ANTENNA RADIATION CHART, by L. J. Giacoletto . 35

Determination, by graphical means, of field strengths radiated by broadcast antennas in terms of power and distance. Correction factors for different types of antennas are included.

DEPARTMENTS

CROSSTALK ............................................................... 9

NEW BOOKS ............................................................. 34

REFERENCE SHEET ................................................... 35

TUBES AT WORK ....................................................... 38

ELECTRON ART ........................................................ 52

THE INDUSTRY IN REVIEW ........................................... 60

PATENTS ................................................................. 71

INDEX TO ADVERTISERS .............................................. 72
New developments; some ephemeral and visionary; many sound and practical, are breaking on the horizon. And today, as in the past, Centralab plays an important part in the electronic industry—in the designing laboratories of manufacturers—on the benches of experimenters—in the "trouble-shooting" service-man's kit and in tiny ham shacks.

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NEW TRANSMITTER EQUIPMENT

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SUPERIMPOSED on the kinescope screen shown above you see the deft hands of an RCA expert assembling a video receiving tube. The anodes (1) and cathodes (2) of these high-fidelity tubes are fabricated by Superior... With other leaders in the field, RCA appreciates that the success of their equipment is dependent equally upon materials of uniform top-quality and outstanding technical skill... Superior Tube Co., Norristown, Pa.
Two New

VARIACS
5 kw and 7 kw

For controlling high power circuits, General Radio Company announces two new VARIAC autotransformers rated at 5 and 7 kva. These are in production with deliveries commencing shortly.

The general design follows that of the small VARIACS; a toroidally-shaped winding on a laminated iron core. Contact to the winding is made by a multiple-contact brush pigtailed to a terminal so that bearing contact resistance is avoided.

The new VARIACS have a number of unique design features which make possible the manufacture of these high power units with the same high efficiency of the popular Type 100 and Type 200 models, thousands of which are in use in the electrical industry. Particular care has been taken in the design of the new units to avoid the possibility of breakdown with the resulting damage to equipment consuming relatively high power.

The Type 50-A VARIAC is rated at 5 kva on a 115-volt circuit and can be connected to supply output voltages continuously adjustable from either 0 to 135 or 0 to 115 volts. The dial is calibrated directly in output voltage and is reversible for either output voltage connection.

The Type 50-B VARIAC is rated at 7 kva on a 230-volt circuit and supplies output voltages of either 0 to 270 or 0 to 230 volts. It, also, is supplied with a direct-reading reversible dial.

Both types are supplied in mounted models only (top photo).

TYPE 50 VARIACS
SPECIFICATIONS

<table>
<thead>
<tr>
<th></th>
<th>TYPE 50-A</th>
<th>TYPE 50-B</th>
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<tr>
<td>Load Rating:</td>
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<td>7000 va</td>
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<td>Rated Current:</td>
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<td>20 amp.</td>
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<td>Maximum Current:</td>
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<td>31 amp.</td>
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<td>Input Voltage:</td>
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<td>230 (tapped for 115)</td>
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<td>Output Voltage:</td>
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<td>0 to 270</td>
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<tr>
<td>No-Load Loss:</td>
<td>60 watts</td>
<td>73 watts</td>
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<tr>
<td>PRICE:</td>
<td>$100.00</td>
<td>$100.00</td>
</tr>
</tbody>
</table>

- Write for Bulletin 451

GENERAL RADIO COMPANY CAMBRIDGE MASSACHUSETTS
Do you NEED a faster, more sensitive relay?

Western Electric 313C Cold Cathode Tube operates on 5 microamperes in 1 millisecond

Because it has no moving parts the Western Electric 313C can operate at such speed... on such low current. This cold cathode tube is faster, more sensitive than any electromagnetic relay. It requires no cathode power or time in starting as does the thyatron. It's ideal for stand-by service.

The 313C can be used as a polarity detector to respond to either a positive or negative voltage. Hundreds of thousands of these tubes are now in this type of service in telephone bell boxes on party lines.

Write for full details to distributors listed below.

**RATINGS AND CHARACTERISTICS:**

- Maximum peak cathode current: 30 m.a.
- Maximum average cathode current: 10 m.a. (average over 1 second)
- Control gap breakdown voltage: 60 volts
- Control gap sustaining voltage: 175 volts
- Main gap breakdown voltage: 75 volts
- Deionization time: 10 milliseconds

**DISTRIBUTORS:**


**Western Electric**

ElectroN ic EQUIPMENT

July 1939 — ELECTRONICS
DIFFICULT engineering problems are most frequently referred to firms who have proven ability along similar lines—to firms with the greatest accumulation of experience, knowledge and facilities.

Development of the greatest spectacle at the N. Y. World’s Fair, the symphony of synchronized sound, color, water, flame, smoke, light and fireworks, which is presented nightly at the Lagoon of Nations to crowds numbering up to 200,000, required the active cooperation of engineers from many fields of endeavor to make it the outstanding success that it is. Not a minor part was the design of the 2000-watt sound system, and Bludworth, Inc., who was given this responsibility, called upon AmerTran to develop audio transformers for handling the large volume of sound with low distortion throughout the band of 28 cycles to 11 kilocycles.

Since the early days of radio, leading manufacturers, radio stations and recording studios have referred their audio transformer problems to AmerTran for solution. Let us submit data on equipment for your requirements.

AMERICAN TRANSFORMER COMPANY
178 Emmet St., Newark, N. J.

AMERTRAN
Speaks to Crowds of 200,000 at the spectacular fountain display, Lagoon of Nations, New York World’s Fair.

Photographs courtesy Cinaudagraph Corp., Stamford, Conn.
There’s a WHALE of a Difference between an

*FP (Fabricated Plate) CAPACITOR

and a Condenser that just looks like an "FP"

*NOT etched Construction

There’s a difference in performance as wide as day and night because there is a difference in construction that isn’t even comparable.

Mallory FP (Fabricated Plate) Capacitors are manufactured under an exclusive patented process developed as the result of months of research and experimenting, plus an investment involving an expenditure of over one hundred thousand dollars.

The characteristics and functioning of these capacitors is so decidedly superior that more than a million are now in use as original equipment . . . and millions more are scheduled to be used in the coming months.

It may be a sincere form of flattery to be imitated . . . but you should know that there is far more to a Mallory FP (Fabricated Plate) Capacitor than a modernized clean-cut compactness. There is no condenser, regardless of appearance, that will give you FP (Fabricated Plate) characteristics. If you want the ultimate in performance and savings . . . be sure it’s an FP (Fabricated Plate) Capacitor.
CROSS TALK

CATS AND DOGS • • • Our London correspondent vouches for this modern application of scientific principles to communication.

By pumping a smell of cats into subterranean coaxial cables, British Post Office engineers have been able to trace leakages in the copper tubes that surround the conductors.

The cables run for 16 miles to the new transatlantic radiotelephone receiving station under construction near Rochester. Normally, a surrounding copper tube is pumped full of air to maintain a high electrical insulation. Leakages can put the station out of action.

When a gas-smelling of cats was introduced into the tube a Labrador retriever taken along the route of the cable detected 14 leaks three feet or so under the surface. Wherever the dog attempted to dig repairs were found to be necessary. The taking up of two miles of cable was avoided by using this dog and cat-gas method.

Incidentally, in America Bell System engineers have made a new telephone cable with 4,242 separately insulated wires in it. Cable has same diameter (23 inches) as its predecessor which had only 3,636 wires. This all came about by decreasing the thickness of the insulation around each wire from 0.008 inch to 0.004 inch.

VU-DB • • • The following letter from H. A. Affel, Assistant Director of Transmission Development, Bell Laboratories is self-explanatory.

"I was interested in the chart 'VU-DB Relationships' which appeared in the May issue of Electronics. In printing such a chart, however, I believe its limitations should be very carefully pointed out. A chart of this sort can, of course, apply only to sine wave measurements and the labels on the curves (e.g. 0 vu = .001 watts) are only true for sine waves."

The principal use made of volume indicators is to measure volume levels of speech and program waves. As pointed out in the article in your February issue by H. A. Chinn, R. M. Morris and myself, the reading of a volume indicator on such waves is determined as much by its dynamic characteristics as by its sine wave calibration. Different old type volume indicators calibrated on .006 watts may read on particular programs anywhere from 6 to about 12 db differently from one of the new standard volume indicators calibrated on .001 watts, where the chart leads one to expect a fixed difference of about 8 db.

"The whole point is that 0 vu does not equal .001 watt or any other value of power, but is that level of a program wave which gives a reading of 0 vu on a standard volume indicator which is calibrated with .001 watt of sine wave power. A speech wave at a level of 0 vu has instantaneous peaks which are several times .001 watt and an average value of a fraction of that power. It is important to understand the philosophy that volume levels are not directly related to power, except in the rare case where a sine wave is being measured, but are, quite arbitrarily, merely the readings of an instrument which is calibrated and read in an agreed upon way.

"I wish to call your attention further to a definite error in the chart. One of the curves is based on a power of .0125 watt in 600 ohms. So far as I know, this value has never been used by anyone. Some of the broadcasting companies have, however, employed a calibration of 2.5 volts or .0125 watts in 500 ohms, for certain old types of instruments. On the average, although not on individual programs, these instruments so calibrated will read the same as certain other instruments calibrated with .006 watt in 600 ohms."

W2XBS • • • In the middle of the Iams-Rose paper on the Orthicon at the New York IRE meeting in June, the loud speaker system began to spout a nice program from the NBC television station on top Empire State. In the McGraw-Hill building, people testing a Filmo projector have been astonished to get the same programs. Years ago, when WEAF was on top the Bell Labs at 463 West Street, it was lots of fun to open up the grid circuit of a repeater and to pick up broadcasts from the roof.

TALKING BOOKS • • • On June 7, the President signed bill H.R.5136 enabling the Library of Congress to let contracts for the making of talking books for the blind to non-profit-making organizations rather than being forced by law to let these contracts to the lowest bidders for them. Since the American Foundation for the Blind, which produced the first talking book in 1934, and the American Printing House for the Blind operate on a non-profit basis, record quality should be such that the user of the record gets the maximum benefit and enjoyment from it. Large research organizations, such as the Bell Laboratories and RCA Victor, have aided in this work, publishers, authors and others have been paid only token royalties—all in the common aim of providing the blind with recordings of maximum value at lowest cost to the Government. There is no money to be made in this business because the volume is small. Therefore there seems little need for commercial concerns to compete with the non-profit groups on a price basis.
Sound

Experimental 100-watt loud speakers on test during early days of New York World's Fair construction. In spite of steam shovels and other noise-making machinery, the battery covered an area of 1½ mile radius.
A new and greatly improved form of the iconoscope uses low-velocity electrons for scanning, thereby avoids spurious signals, obtains storage efficiency ten to twenty times that of the iconoscope, and produces an output current linearly related to the light input.

O n June 7th, Albert Rose and Harley Iams, of the RCA Manufacturing Company Research Laboratories at Harrison, revealed to the New York Section of the I.R.E. the details of a new developmental television pick-up tube which, in the opinion of your editors, is one of the most significant advances in television electronics since the advent of the iconoscope itself. The new tube's formal name is "Orthiconoscope" ("Orthicon" for short) from the Greek root ortho meaning "straight" and iconoscope for "image-viewer." The name derives from the fact that the curve between input light and output current is a straight line, in contrast to the similar curve of the iconoscope which is not linear. In photographic parlance the new tube is a "gamma-unity" device, whereas the gamma of the conventional iconoscope is in the neighborhood of 0.7. The new tube thus provides a more contrasty picture from a given subject than can the conventional pick-up tube.

The linearity of the device is but one of its advantages. By using low velocity electrons for scanning the mosaic image plate, the effects of secondary emission from the surface of the plate are made negligibly small. No spurious "dark-spot" signal is generated, and the uneven shading so troublesome in iconoscope pick-ups is thereby completely eliminated.

Finally, and perhaps of greatest significance from the long range point of view, the storage efficiency of the new tube is substantially 100 per cent, compared with 5 to 10 per cent in the iconoscope. Ultimately, therefore, the new tube may be made to have an overall sensitivity 10 to 20 times that of the iconoscope.

The new tube has been under development for several years, and it combines a great many techniques which have appeared in other devices during that time. The radical difference, however, between the orthicon and all preceding forms of the iconoscope is the use of low-velocity electrons for scanning. This use has made necessary the development of a new technique of scanning, which combines the effects of a magnetic field and an electric field. This new deflection technique is a striking example of the practical application of low-velocity electron optics.

Before describing the tube in detail, it is worthwhile to list the specifications of the tube in its present experimental form: the tube is a cylindrical structure about 20 inches long and 4 inches in diameter. The image plate on which the optical image is focussed is located at one end of the tube and measures about 2 by 21 inches. The picture resolution obtainable within this area exceeds 400 lines, and up to 700 lines has been achieved in some cases. These values equal or exceed the capabilities of the present television standards. The relationship between light input and current output is linear from zero light to the value of light which exhausts the beam current (about one microampere). The equivalent noise current due to a typical amplifier is about 2 to 3 thousandths of a microampere, whereas the maximum output signal current of the tube, under the same circumstances, is from 0.5 to 1.0 microampere. The maximum signal-to-noise ratio is accordingly from 300 to 500 times. The sensitivity of the present models is somewhat greater than that of the iconoscope.

To appreciate the advantages of the newly-developed tube, it is necessary to recall the operation of the conventional iconoscope and to show
how the use of a high-velocity scanning beam imposes limitations on the operation of the tube. These limitations were reviewed by Mr. Iams as follows: in the conventional iconoscope (Fig. 1) a mosaic composed of many tiny photosensitive globules is exposed to the optical image. The globules emit electrons under the influence of the light and thereby assume a positive charge in proportion to the amount of light falling on them. Since the globules are insulated from one another, the charge distribution so acquired cannot redistribute itself, but remains stored on the surface of the mosaic until the charge equilibrium is restored by the scanning beam. This beam is formed in an electron gun in a side-arm of the tube, is directed toward the plate and is deflected by electromagnetic deflecting fields to cover the plate in a pattern of interlaced scanning lines. The beam employed in the conventional iconoscope is accelerated to a velocity equivalent to about 1000 volts. The necessity of employing an electron velocity as high as this rests in the need for maintaining a sharply focussed beam which will retain uniform focus over the entire area of the mosaic, and which will excite a high level of signal current.

When the electron beam hits the globules of the mosaic its immediate effect is to liberate secondary electrons from them. The number of secondary electrons liberated depends, among other things, on the positive charge which the mosaic has assumed due to the photoelectric emission. In consequence the secondary electron current from the mosaic varies with the charge distribution induced by the optical image on the mosaic. The variations of this secondary electron current, when collected by the collector electrode of the tube, constitute the signal current from the tube. A common misunderstanding of the operation of the iconoscope is that the signal arises from variations of the beam current itself; that is not true since the impedance of the scanning beam is substantially infinite. Hence the secondary emission effect is of primary importance in the operation of the tube.

But, according to Mr. Iams, the secondary emission has other effects which are not desirable, and which in fact limit the operation of the tube. In the first place, there are more secondary electrons liberated than there are electrons received from the scanning beam, since the secondary emission ratio is greater than unity. But the mosaic plate is insulated, therefore on the average the number of electrons leaving it must equal the number gained. Accordingly only part of the secondary electron current can be collected; the remainder must fall back on the mosaic plate in a shower of electrons (Fig. 2). If the shower were perfectly uniform over the whole plate area, the only effect would be a loss of the distribution of stored charge. But the shower is not uniform, due in part to local irregularities in the secondary emission ratio on the plate, and due also to the effect of differences in the field existing at the plate surface. The shower of secondary electrons thus produces a random charge distribution which is superimposed on the regular charge distribution due to the optical image. The random distribution
gives rise to a spurious signal, known as "dark-spot," which has no direct connection with the desired picture, and which has the effect of causing an unevenness in the background shading of the reproduced picture. A special shading-correction generator must be used to compensate for this spurious signal, and this generator must be controlled continually by an operator during each transmission. Even at best the shading-correction is not perfect, hence it is usual to notice a white "flare" at the edges of the picture.

The presence of the high secondary electron emission has still another undesirable effect. It produces a retarding field at the surface of the mosaic which inhibits the emission of the photoelectric electrons under the influence of the optical image. Therefore the photoelectric current is not saturated, but has a value roughly one-third of saturation. This reduces the possible output of the camera tube by the same factor, and accounts, in part, for the low photoelectric efficiency of the tube. The stored charge on the mosaic is, in addition, partially neutralized by the shower of returning secondary electrons, and this effect reduces the net photoelectric effect by another factor of three. The total output current is thus reduced by two factors of roughly three, and the output signal current is accordingly one-ninth what it would be if the photoelectric emission were saturated and there were no loss of stored charge. Accordingly, the overall efficiency of the conventional iconoscope is, on the basis of one-ninth the possible output, only 11 per cent. Actual measured values of efficiency range from 5 to 10 per cent.

It follows that the advantage of the iconoscope principle is severely reduced by the presence of the secondary electrons, although part of the secondary electron emission serves a useful purpose in developing the output signal current. In theory the iconoscope sensitivity, due to the principle of storing light in the form of a charge image, is multiplied by the number of picture elements in the image, or by from 100,000 to 200,000 times. In practice, only from 5 to 10 per cent of this increased sensitivity is realized. The new tube, on the other hand, permits an eventual realization of the full advantage of 100,000 to 200,000 times.

**Getting Rid of Secondary Emission in the Orthicon**

To improve on the conventional iconoscope, as shown by the authors, the indicated course of action is to get rid of the secondary emission (and thus obtain saturated photoelectric emission, no loss of stored charge and no spurious signal) and at the same time to substitute another agency for the secondary electrons in forming the picture signal. In the new tube, Messrs. Rose and Lams accomplish this result by using a scanning beam composed of low-velocity electrons. The mosaic target is maintained at the potential of the cathode of the electron gun. Consequently, the electron beam travels between two electrodes (the cathode and the mosaic) which have no difference of potential between them. Since the electrons start off at a very small velocity at the cathode, they must meet the mosaic with an equally small velocity. The low-velocity beam electrons, when they impinge on the mosaic, are in no position to excite secondary emission, and in fact no secondary emission effects have been observed. Furthermore the low-velocity beam electrons act as the agency for withdrawing the picture signal from the mosaic and conducting it to the collector electrode, whence it travels to the external circuit. The maximum value of the signal current is accordingly equal to the maximum value of beam current, which in the present experimental tubes is about one microampere. Passed through a 100,000-ohm load resistor, this output current is equivalent to a 0.1 volt output signal.

But the use of a low-velocity scanning beam is not without its difficulties. In the first place such low-velocity beams are very subject to deflection by stray magnetic or electric fields. In the second place, low-velocity beams are in general subject to severe defocussing if the beam does not hit the scanned surface directly at right angles. Thus, if the scanned beam hits the surface perpendicularly (see Fig. 3) and if the mosaic potential is the same as the cathode potential, the electron comes to rest at the surface, turns around and travels back toward the cathode directly away from the surface. The defocussing which occurs is due only to the emission velocity of electrons from the cathode. On the other hand, if the beam hits the surface at an angle as shown at the
bottom of Fig. 2, the electrons “skid” along the surface tangentially and are reflected back toward the cathode at an angle equal to their angle of arrival. The point of contact of the electron with the surface is correspondingly ill-defined, that is, defocussing occurs.

To avoid this effect, it is preferable that the scanning beam impinge on the mosaic perpendicularly, no matter at what point in the scanning pattern. This precludes the use of conventional deflecting technique, in which the scanning beam is caused to scan the surface by the application of deflection forces which change the direction of the beam. In this latter case, the electron beam hits the outer edges of the mosaic at an angle.

To produce a method of scanning in which the beam maintains a perpendicular relation to the mosaic at all points, it is possible to employ a deflecting system which changes the angle of the beam temporarily. Thus, consider the scanning arrangement shown in Fig. 4. The beam enters the deflecting system as a stream of electrons from the gun. The deflecting system imposes a change in direction which persists only so long as the beam is within the deflecting field. Immediately after the beam emerges from the plates, it resumes its forward course and travels from its deflecting plates to the mosaic in a line parallel to the axis of the tube, and finally hits the mosaic perpendicularly.

To produce a deflecting system of this type in practice is not a simple job. Before it was successfully accomplished several preliminary attempts were made, using rather cumbersome apparatus. One of the early forms of the tube is shown in Fig. 5. The image to be televised is focussed optically on a mosaic plate as shown. At right angles to this plate is a photocathode which acts as the source of the scanning electrons. Focussed on this photocathode is an unmodulated spot of light derived from a conventional cathode-ray picture tube. This spot of light is deflected in the standard interlaced scanning pattern by a deflection system associated with the cathode-ray tube. Consequently the photocathode is scanned by the light beam and liberates electrons which arise from the photocathode in scanning formation. The electrons leaving the photocathode are guided to the mosaic by circular lines of magnetic force, which are produced by the iron yoke shown, energized with direct current. It is a principle of electron optics that electrons of low velocity, once started along a line of magnetic force will follow this line of magnetic force unless otherwise constrained. There being no other fields of force present, the low-velocity photoelectrons from the photocathode travel around the quarter circle until they reach the mosaic target.

There they discharge the mosaic elements in accordance with the field distribution set up by the optical image focussed on the mosaic. The picture signal thereby produced is then taken from a signal coating on the reverse side of the mosaic. It will be noted that the scanning electrons are themselves produced indirectly by photoelectric action, that they impinge on the mosaic perpendicularly, and that they are of low velocity (their velocity when they hit the mosaic is substantially the same with which they were emitted from the photocathode).

Another evolutionary form of the tube, described by the authors, is shown in Fig. 6. Here a two-ended tube is used. At the right end a translucent photocathode has focussed on it the optical image to be reproduced. An image in electrons is thus formed and this image is focussed on a two-sided mosaic, where electron multiplication increases the effective charge and stores it. From the left-hand end of the tube another translucent photocathode is used to develop the scanning electrons. On this photocathode the image of the fluorescent scanning spot is focussed, from a cathode-ray tube which is deflected in the customary manner. The electrons leaving the left-hand photocathode travel toward the two-sided mosaic at low velocity and are guided thereto by the action of axial lines of magnetic force set up by the coil of wire external to the tube. These electrons scan the mosaic, hitting it perpendicularly at all points, and the video signal thereby generated is derived from the two-sided mosaic.

Both of the above described forms of tube operate satisfactorily but they require a great deal of auxiliary apparatus, which would be difficult to include in a camera housing of practical size. In addition, the detail of the picture depends on the size of the scanning spot developed by the auxiliary cathode-ray tube, and the size of this spot may suffer from the effects of halation, etc., when sufficient light is obtained from it to excite the desirable number of scanning electrons. Consequently, research was undertaken to devise a tube using a thermionic cathode (rather than a photoelectric one) for the scanning electrons.

The Present Developmental Form of the Orthicon

In developing a thermionic cathode type of tube, described by Dr. Rose, the first question was that of the electron gun. A very simple form was used, illustrated in Fig. 7. The cathode is a flat surface, directly in front of which is an aperture approximately one mm in diameter. This aperture defines a bundle of electrons, which is further reduced in cross-section by a pin-hole aperture (4/1000ths inch diameter). The positive potentials applied to the apertures are of low magnitude, so the beam is composed of low-velocity electrons, and the cross-section of the beam is narrow and well defined.

(Continued on page 58)
Applications of Copper Oxide Rectifiers

By Leo L. Beranek
Craft Laboratory, Harvard University

In recent years improvements in manufacturing technique have made copper oxide rectifiers suitable for use at high frequencies, such as encountered in radio circuits and carrier telephone systems. Although the voltage vs current characteristic of the copper oxide disc can be duplicated to a certain extent by vacuum tubes, certain definite advantages exist in favor of the former. For example, the disc are much smaller than an ordinary vacuum tube. Their electrical characteristics are permanent throughout their life and are free from variations which would occur due to change in supply voltages. Also, their life is long.

The copper oxide rectifying element proper consists of a copper plate or disc, one side of which is covered with a layer of cuprous oxide. On top of this is placed a thin layer of graphite which serves to prevent any counter-rectification at the interface between the cuprous oxide and the connecting electrodes. Over this layer a thin lead sheet is pressed, making contact with the uneven surface of the graphite. In practice these disc assemblies are usually mounted in stacks of two or more clamped tightly together to insure complete and permanent contact.

The current-voltage characteristic is determined by three factors: The purity of the mother copper, the oxygen content of the atmosphere in the oven during oxidation and, most important of all, the cooling technique employed. Thus it might be expected that units made by different manufacturers would have considerably different characteristics. This is clearly shown in Fig. 1, in which the static characteristics of four units of different manufacture are shown. The resistance plotted is taken as the ratio of the bias voltage to the total resulting current. The resistance of a copper oxide disc varies inversely as the temperature. These variations are of the order of 4 to 8 per cent in the temperature range of 32° to 100° F. Humidity has also been shown to be an important cause of long time variations in the characteristics. Circuits employing 3/8 inch diameter discs, commonly used as meter rectifiers and as elements in modulating circuits, should be operated so that not over three volts (peak) is placed across any one disc in the non-conducting direction and so that no current larger than 20 milliamperes flows in the conducting direction. These values can be exceeded somewhat for short periods of operation, but this may lead to accelerated aging.

Equivalent Circuit for A-C Response

The variational behavior (equivalent circuit for a-c response) of the copper oxide discs can be represented by a resistance in parallel with a capacitance. These are by no means constant, however, both being functions of frequency, bias voltage, and magnitude of the applied signal. Bridge measurements of the small-signal impedance were made on discs taken from "Varistor" units. Figure 2 shows the resistance and capacitance of a single disc plotted as a function of bias voltage. Consideration of the static characteristic curve for this disc shows that for values of E between 0 and 0.02 volts.
the current can be expressed by
\[ I = aE + bE^2; \]
for \( 0.06 < E < 0.25 \),
\[ I = c(e^E - 1); \]
and for larger voltages \( I \) again becomes a linear function of \( E \). This sort of characteristic is difficult to express mathematically, even when the shunt capacitances are neglected. It has been experienced that simple circuits using only one varistor can be most accurately treated for frequencies below 10,000 cycles by graphical analysis of the static characteristic curves. Even this becomes unwieldy when several elements are used and more complex circuits can only be handled by mathematical approximations.

Application as Rectifier vs. Modulators

The applications of copper oxide rectifiers can be classified in two broad groups: First, as rectifiers to obtain a direct current bearing some relation to the applied alternating voltages and, second, as modulators or demodulators for frequency conversion. This paper will be concerned only with applications of the small \( \frac{3}{8} \)-inch discs.

A familiar example is the a-c meter which uses a copper oxide disc as a rectifying element and a direct current milliammeter as an indicator. Most common of all meter rectifier circuits is the simple bridge circuit shown in Fig. 4a. Its d-c vs. a-c applied voltage characteristic, as shown in Fig. 4b, is linear over the major portion of the scale except when the multiplier resistance is less than several thousand ohms. Figure 4c shows the direct current for a constant applied a-c voltage as a function of frequency for units supplied by four different manufacturers. The falling characteristic on the high frequency end, commonly found in a-c meters, is due to the shunt capacitance mentioned before. This can be compensated by shunting the resistance \( R \) with a small capacitance. The best of the curves in Fig. 4e is shown in Fig. 5 as compensated by the addition of such a shunt condenser. The chief disadvantage of this circuit is that temperature changes directly affect its calibration. A circuit designed to eliminate this difficulty is shown in Fig. 6a. In this case the meter reads essentially peak voltage and hence is independent of moderate changes in the resistance of the oxide disc. The frequency characteristic, Fig. 6b, is largely dependent on the constants of the transformer and on the time constant of the parallel resistor and condenser. The low frequency droop can be raised by increasing the \( RC \) product, while the high frequency droop can be compensated as before by inserting a parallel resistor and condenser between the points 1 and 2. It is essential that rectifier units having high resistance in the nonconducting direction be chosen in order to keep the \( RC \) constant high.

A slightly modified form of the preceding circuit is shown in Fig. 7a. It has been described by Tamm
and Bath and its properties have been further investigated in the Cruft Laboratory. In this circuit, if $E_1$ and $E_2$ are of the same frequency and if $E_1$ is at least three times as large as $E_2$, then the direct voltage measured across points 5 and 6 will be found to be directly proportional to $E_1$ and to the cosine of the phase angle $\theta$ between $E_1$ and $E_2$. The plot in Fig. 7b shows the direct voltage across terminals 5 and 6 vs $\theta$ with $E_1$ as a parameter, for the particular circuit constants of Fig. 7a. One application of this circuit which has been developed is its use as a power meter to measure the energy supplied by a single signal generator to a linear load. It can be used over the frequency range of sixty to five or six thousand cycles without the necessity for using vacuum tubes, thermocouples or any external supply voltage. In this case the voltage across the load is applied at terminals 1 and 2 ($E_1$) and a voltage proportional to the load current is connected to 3 and 4 ($E_2$). Since the direct potential across terminals 5 and 6 is not a linear function of $E_2$, it is necessary to insert an attenuator between the supply voltage and the terminals 1 and 2 and to reduce $E_2$ in all cases to one value, say 2.0 volts. Then if the scale of the direct current indicating instrument has been calibrated to read power directly for $E_1 = 2.0$ volts, it is only necessary to multiply the scale reading by the factor by which $E_1$ has been reduced.

Another feature of this circuit is that if the generator $E_1$ is replaced by a resistance and if a direct potential is applied at the terminals 5 and 6, then a voltage of the frequency of $E_1$ and having a magnitude directly proportional to the d-c bias will appear across this resistance. Two applications have been published and are shown in Fig. 8. In (a) a direct current amplifier is shown whose stability is essentially that of the a-c amplifier. Variations of $E_1$ less than 10 per cent in magnitude will not affect the operation as long as the restriction that $E_1$ be greater than $E_2$, by at least a factor of three is satisfied. In (b) a circuit is shown for measuring variations in the capacitance of a condenser. The magnitude of $E_2$ depends on the degree of unbalance of the bridge. In one application, $C_1$ is a pair of rollers placed on either side of a sheet of moving paper in a paper mill and since a d-c recording galvanometer is connected across the terminals 1-2, variations in paper thickness are recorded continuously as a function of time.

Use as Modulators

Under the second class of applications, copper oxide rectifiers have
found their widest use in carrier telephone systems as modulators and demodulators. For this purpose, four rectifier discs are combined into either a bridge circuit, as shown in Fig. 8a, or into "ring modulators", as shown in Fig. 9b. The operation of the two is essentially the same, the difference lying in the number of frequency components that are desired or can be tolerated in the output circuit. It will be noticed that while a current component of frequency $f$ appears in the output of the bridge circuit, no current component of this frequency appears in the output of the ring modulator. Both circuits are similar to the van der Bijl type of vacuum tube balanced modulator in that the carrier is suppressed from the output circuit to a large degree. However, the copper oxide circuits excel because, due to the stability of their characteristics, a much higher degree of carrier suppression can be maintained. Even without special selection of the discs, the carrier amplitude will be reduced by thirty db in the output and with the balancing method shown in Fig. 10 carrier reductions of one hundred db can readily be obtained and reductions of sixty db can be maintained over long periods of time.

Mathematically, an exact analysis of the operation of the modulator is exceedingly complicated. As is usually found in non-linear circuits, it is simpler to determine first the characteristics of the circuit experimentally and using that information as a guide, make simplifying assumptions in the mathematics which may lead to useful answers. In carrier telephone systems and in many other applications, a single side band is desired, that is, a component whose frequency is equal to either the sum or the difference of the signal and carrier frequencies. Furthermore, it is usually desired that the amplitude of this sum or difference frequency bear a linear relation to the amplitude of the impressed signal and that a minimum of distortion products be generated in the modulating process. Therefore, if, for the circuits of Fig. 9, certain reasonable generator and terminal impedances are selected, valuable information should be obtained from a contour diagram of constant $E_{II}$ on the $E_{II}$ vs $E_{II}$ plane. Such a plot is shown in Fig. 11. From these contours it may be deduced that if $E_{II}$ is large in comparison to $E_{II}$, then the sum and difference terms vary linearly with $E_{II}$ and are independent of $E_{II}$. This is just the performance that is desired. Also measurements show that lowest harmonic distortion occurs under this condition. A similar result is obtained for the ring modulator.

When the carrier voltage is large in comparison to the signal voltage, then the resistance of the copper oxide discs will be controlled almost entirely by the carrier except during the very short time that it is passing through zero. As the carrier voltage passes through a cycle, pairs of the oxide discs become alternately conducting or non-conducting. This occurs in both types of circuits, but for purposes of analysis the ring modulator is more convenient. In this type, the equivalent circuits of Fig. 12 can be drawn for the two

(Continued on page 68)
THE increased use of the cathode ray oscilloscope in the study of transient or recurring phenomena has necessitated the application of photography in order to obtain a permanent record of the trace on the screen. The photography of cathode ray tube screen traces involves a number of problems, and attention should be given to: (1) the speed at which the electron beam travels across the fluorescent screen, (2) the spectral radiation characteristics of the cathode ray tube screen, (3) the aperture of the taking lens, (4) the spectral sensitivity of the photographic material, (5) the magnification at which the photograph is made, (6) the voltages applied to the electrodes of the cathode ray tube (and especially the second anode voltage), and (7) the developing conditions.

The writing speed, or the velocity with which the electron beam travels over the screen of the cathode ray tube, is of greater fundamental significance in discussing exposures than tables covering the general case of recurring phenomena because such tables are not applicable to the recording of single sweeps of non-recurring waves. The writing speed, on the other hand, is applicable both to recurring and non-recurring phenomena.

From the geometrical optics of a simple lens, it may be shown that the amount of light reaching the film for a given light source varies as \((1 + M)^2\) where \(M\) is the magnification. For full size photographs, \(M = 1\), but more often the photographic image is smaller than the original so that \(M < 1\).

The intensity of the trace on the cathode ray tube screen is roughly proportional to the second anode voltage, if all other electrode voltages are maintained constant, or is roughly proportional to the square of the control grid voltage if other electrode voltages are held constant. Thus, if proper exposure data is available for one set of known voltages, the exposure for other electrode voltages can be estimated.

Most developers are satisfactory for oscillographic photography. For films of normal size a high energy developer should be used and the film developed to maximum contrast in order to record maximum writing speed. On the other hand, if miniature negatives are used, in which the image must be considerably enlarged, a fine grain (low energy) developer may be required, although this will reduce the writing speed which can be recorded satisfactorily.

It now remains to determine the maximum writing speed for which satisfactory traces are obtained. In some experimental work to determine this speed, a three inch cathode ray tube was operated at normal conditions, and a 5000 cycle sine wave from a beat frequency oscillator was impressed on one set of plates and a sweep voltage on the other set of plates. For such sinusoidal traces, the displacement from the reference axis is given by

\[
s = 0.5 A \sin (2 \pi ft)
\]

where \(A\) is the peak-to-peak amplitude and \(f\) is the frequency of the voltage. The writing velocity of the electron beam is the time rate of change of the displacement, or

\[
V_w = ds/dt = A \pi f \cos (2 \pi ft)
\]

which is a maximum for \(\cos (2 \pi ft) = 1\).

Using these relationships, a series of exposures were made. The image on the film was that which satisfied the minimum requirements for projection printing on a contrast paper. The writing speed was then determined from the size of the image, the frequency of the wave and the aperture of the lens system. The results of this experimental work are shown in Table I which gives the writing speeds for several films for two different kinds of screens, with normal operation of the three-inch oscilloscope and a lens aperture of f/3.5.

The writing speeds should not be regarded as being absolute. They are given as representative, approximate values determined from many photographs and serve to show results which may be normally expected.

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**Table I—Writing Speeds for Oscilloscope Traces**

<table>
<thead>
<tr>
<th>Film</th>
<th>Writing Speed in mm/sec Green screen</th>
<th>Blue screen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastman Super XX</td>
<td>47,000</td>
<td>125,000</td>
</tr>
<tr>
<td>Agfa Ultraspeed</td>
<td>22,000</td>
<td>60,000</td>
</tr>
<tr>
<td>DuPont Superior</td>
<td>14,000</td>
<td>37,000</td>
</tr>
</tbody>
</table>

*This table is prepared for normal operation of three inch oscilloscope, a lens aperture of f/3.5, with films processed in fine grain developer.

---
In an effort to enable the radio listener to interpret music and other sounds normally, as if he were in the studio or concert hall, Lincoln Walsh has designed and constructed the high quality radio receiver described in this article.

Once upon a time a radio engineer, who attended a symphony concert, said, "I didn't like it because the music was too high pitched. The violins were too tinny and the horns too brassy. On the low end of the scale," he continued, "there were some very low notes which didn't belong there." This tale is not as fantastic as it sounds (actually, it is true) because most of the radio receivers available today reproduce music in such a manner as to give a new and poorer interpretation to music.

Wide band distortionless receivers will reproduce faithfully all sounds from the transmitter. However, with broadcast stations spaced 10 kc apart in the frequency spectrum, there are times when one station will interfere with the station on the adjacent channel. In metropolitan areas the signals from the strong local stations are free from interference a large part of the time and full advantage may be taken of the wide band receiver. But interference is often present, especially on winter evenings when transmission conditions are very good and the signals from distant stations are relatively strong and some means must be used to eliminate it as much as possible. The interference is of three separate and distinct types as follows:—1. 10 kc heterodyne whistle caused by the two carriers beating with each other. 2. Chatter, a high pitched, unintelligible sound caused by the desired carrier beating with the nearer side band of the adjacent channel carrier. 3. Crosstalk which is caused by the adjacent channel signal carrier beating with its own sidebands.

Elimination of Interference

Crosstalk can be removed only by narrowing the selective circuits and in this case variable band width i-f circuits are most convenient to use. The 10 kc whistle can be removed by the use of a 10,000-cps band-elimination filter, but in the receiver described, this is unnecessary because the whistle is removed by the chatter removal elements as is shown later. The method of removing the chatter is more involved and may best be shown by an example. Let it be assumed that the i-f band width has been narrowed for crosstalk elimination so that the signal is down 10 db at 10,000 cps and that the adjacent channel signal is one tenth as strong as the desired signal with both signals 30 per cent modulated. The Figure on page 22 represents the incoming signals and their sidebands at the detector. The desired signal, A, has a relative strength of 100 and its sidebands a strength of 15. The adjacent channel or interfering signal, B, has a relative strength of 3.33 and its sidebands, 0.3. For the purposes of this discussion the output of the detector is assumed to be proportional to the product of the carrier and sideband amplitudes. This is not strictly correct for a diode detector, but it approximates the actual condition. The relative amplitudes of the desired signal and the three types of inter-
RADIO RECEPTION

The receiver is contained in two chasses: the r-f and i-f units and first audio stage are in the left chassis and the audio power amplifier and power supply are in the right chassis. All controls and a heater transformer for the tuner tubes are mounted on the tuner chassis.

ference under the stated conditions are as shown in Table 1. It has been shown by experience that the amplitude of the interference should be at least 60 db below the level of the desired signal. In this example, a

| Table 1—Amplitudes of the Desired Signal and Three Types of Interference |
|-----------------------------|-----------------|------------------|
| Desired                     | 100 × 2 × 15 = 3000 = 0 db |
| Heterodyne                   | 100 × 33.3 = 333 = -19 db   |
| Whistle                      | 100 × 0.3 = 30 = -27 db     |
| Chatter                      | 33.3 × 2 × 0.5 = 33 = -69 db |

fairly severe case, the cross-talk is just about on the border line and something must be done about the chatter and heterodyne whistle.

Chatter may be described as inverted speech with a base frequency of 10,000 cps. Most of the energy of sound lies in the range of 100 to 2000 cps. Hence, most of the energy of chatter lies in the range of 8,000 to 10,000 cps. Therefore, the solution of the problem would seem to be to reduce the i-f half band width to between 7,000 and 8,000 cps and to reduce the audio response above 8,000 cps very rapidly so as to get as much fidelity as possible out of the desired signal. The 10-kc heterodyne whistle is also eliminated because the reduced audio response at 10,000 cps brings the level of the whistle well below the necessary — 60 db level. If there is still interference under these conditions, the i-f band width must be narrowed still further and a lower audio cutoff frequency must be used.

After several years of experimenting with both t-r-f and superheterodyne receivers, it was concluded that the best way to get variable band width was to get it in the i-f circuits of the superheterodyne receiver. It is obtained by the use of i-f transformers of variable coupling in which the secondary coils of the three transformers are moved simultaneously by means of cams mounted on a shaft which also operates switches to change the cutoff frequency of the low pass filter used to reduce the audio response as mentioned above.

On the wide range position the transformers are at the point of maximum coupling with the first two overcoupled so as to give double peaks which are separated by about 35 kc. Mutual inductive coupling is used for three reasons: 1. The two peaks of the resonance curve will be of equal height only if no losses are introduced in the coupling reactance; inductive reactance is the only type of coupling which has no losses. 2. Mutual inductance is the only type of coupling which will move the peaks out from the center equally and will not vary the center frequency. 3. Any number of steps are possible. The resonance curve of the third transformer has a rounded top whose shape and width is varied by the variable coupling and the detector loading so as to be complementary to the curves of the first two transformers. This gives an
overall resonance curve of the i-f system which is flat over a range of 32 kc which means the audio frequency response is flat to 16,000 cps. In the most loosely coupled position, the circuits are sufficiently undercoupled to get the maximum selectivity of which the i-f system is capable. Since the circuits are undercoupled, it is possible in this setting to align the i-f tuning condensers to a single peak with only a microameter in the detector circuit and a source of 455 kc signal, even more accurately than by much more complicated methods as are now used in production alignment methods of overcoupled i-f systems.

**Low Pass Filter**

The low pass filter used in conjunction with the variable i-f band width to eliminate interference is of the Campbell type and consists of eleven elements. There are four series inductances, five shunt capacities, and two mutual inductances. The characteristic of this filter in position B is as follows:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Signal down</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 7200 cps</td>
<td>0 db</td>
</tr>
<tr>
<td>8000</td>
<td>30 db</td>
</tr>
<tr>
<td>9000</td>
<td>50 db</td>
</tr>
<tr>
<td>10000</td>
<td>70 db</td>
</tr>
</tbody>
</table>

Experience has shown that it is desirable to vary the audio range in five steps. On the 7500 cps range, B, it is possible to receive signals as low as 100 microvolts without interference. Signals weaker than 100 microvolts can be received on the 5500 cps position, C, without interference and with quality considerably better than on a conventional receiver. For those conditions where high selectivity is necessary, such as high noise level or distant station reception, the 3600 cps range position, D, is used. For extreme conditions the 2500 cps range position, E, is used.

**R-F System**

The purpose of the r-f stage is primarily to reduce noise and the image frequency response. The r-f band width is wide enough to accomodate the widest i-f band and is of fixed width. The antenna circuit is double tuned and double peaked with the peaks separated by about 25 kc. The r-f stage is single tuned and single peaked and is made to have high resistance so that the peak will just about fill in the valley of the double peaked resonance curve of the antenna stage. The r-f system then has an overall resonance curve which is flat within one db over a band width of 25 kc, which will pass 12,000 cps without attenuation, and 16,000 cps will be down 6 to 8 db. Very little effort is spent to make the response flat to 16,000 cps because the transmitter characteristics of most stations drops off at about 11,000 cps. By reducing the 16,000 cps response by 6 db, it is possible to increase the r-f system gain by 3 db thereby decreasing the receiver hiss level by 3 db.

**A-V-C System**

The a-v-c system holds the detector voltage at 14 volts plus 0 minus 3 db over an antenna voltage range of two volts to 100 microvolts. The a-v-c consists of a diode fed thru a very broadly tuned transformer from a separate i-f tube. No delay is employed.

**Elimination of Distortion**

In a high quality system the speakers respond to frequencies up to 16,000 cps and will therefore respond to all audible harmonics. Hence, distortion in a high quality receiver is much more serious than in a conventional receiver. Distortion in the r-f and i-f tubes is minimized by operating them far below their capacities. Detector distortion is held as low as possible by operating the detector at 14 volts dc which is on the straight line portion of its characteristic and not so high that the second i-f stage overloads.

Any iron in the audio circuits will introduce a small amount of odd harmonics. The amount of harmonic increases with the hysteresis loss of the iron and decreases with increasing a-c flux density. Therefore, the audio circuit is resistance capacity coupled up to the input to the output stage. A special core steel having extremely low hysteresis is used and the high levels at which these transformers operate combine with low hysteresis to bring the distortion from this source to entirely negligible values.

Low mu triodes are used throughout the audio stages for the reason that all of the tubes available for audio amplification, they have by far the lowest audible distortion. The audio amplifier operates over a range of 15 to 16,000 cps flat within one db and has an output of 15 watts with negligible distortion and 30 watts with very low distortion. It may seem that this is too great for homes. If an average power of three watts is desired and the incoming signal has an average modulation of 30 per cent and has peaks of 90 per cent, the peak power of the amplifier to reproduce the signal faithfully must be 9 times the average power required or 27 watts. Also, with a high quality receiver, it has been noted that there is a strong tendency to increase the volume to approximately the same loudness as in the original auditorium. Hence, a thirty watt amplifier is not much larger than the minimum required.

A pair of 2A3s in push-pull operating in Class A' are the output tubes and are preceded by a 6A5G driver stage. A separate rectifier supplies fixed bias for the grids of the 2A3s. If for any reason the fixed bias should fail, a relay automatically switches the tubes to self
bias and they will operate at reduced output. A feedback circuit is used to reduce the amplitude distortion at high levels. The driver stage, the fixed bias and the feedback are used so as to increase the effective output of the amplifier. If it were operated without them it would have a power output of about ten watts with slight distortion. When the fixed bias is added the output is increased to fifteen watts. With fixed bias, the low impedance driver stage, and feedback in the circuit, the amplifier will operate at 50 watts or very close to its absolute peak power with slight distortion.

**Speakers**

Two speakers, one woofer and one tweeter, preferably mounted in a wall, are used. The woofer responds to frequencies up to about 8,000 cps and its resonance frequency is lower than 50 cps. The tweeter covers the range from about 5,000 cps to 16,000 cps, falling off slightly at 14,000 cps.

It has been found to be better to have the two speakers overlap considerably in their frequency ranges instead of having a sharp transition point. It is necessary to have as large a baffle as possible so that the very low notes will be properly reproduced. Therefore, whenever it is possible the speakers are mounted in the wall.

Two speakers are used for the following reasons: In any speaker there are two sets of waves set up in the paper cone, one is longitudinal and one is lateral. As long as the rates of propagation of these waves are equal, the cone motion is essentially that of a piston, and this is the case at low frequencies. But at the higher frequencies, the longitudinal wave travels faster and reflects differently from the edge than the lateral wave, and therefore the motion of a given point on the cone is of a highly complex nature. To build a speaker covering the range from 40 to 16,000 cps in which all of these factors are properly controlled is substantially impossible in the present state of the art and it is better to build two speakers of different characteristics which supplement each other. There have been specially developed for this receiver, woofer and tweeter speakers of moderate cost which give excellent results. — C.W.

**Electronics — July 1939**
Program Failure Alarm for Broadcast Stations

To give a positive indication of a program failure shortly after it occurs and to avoid giving false alarms during intervals for station identification or other reasons, the instrument described herein was constructed.

By HOWARD A. CHINN and ROBERT R. MOE

THE master control room of a modern network broadcasting station frequently has facilities capable of simultaneously transmitting eight or more different programs to outgoing program lines for distribution to radio stations in various sections of the country. Each of the outgoing radio lines is generally monitored by means of a volume level indicator and a loudspeaker.

Because of the many duties performed by the technicians in the master control room, it is not generally feasible to watch continually the volume indicators and dependence is largely placed on aural monitoring for checking outgoing programs. With several loudspeakers operating simultaneously, it is sometimes difficult to detect a failure of any individual channel. This is particularly true when a given program is being transmitted to more than one of the outgoing lines, as several monitor speakers are then reproducing the same program.

A study was therefore undertaken to determine the merit of the various means for avoiding unnecessary delay in the detection of a program failure. One of the experimental devices developed was designed to give an alarm a predetermined time after a program interruption occurred. It is believed that this unit may be of interest to others.

Description of the Alarm

The CBS experimental Program Failure Alarm is a program-operated relay which gives a visual-aural alarm when program fails on the line which the unit is monitoring. An adjustable time delay has been incorporated in the unit so it will not operate and give a false alarm during station identification intervals or during other short pauses in program continuity.

A schematic wiring diagram of the device is shown below. The first tube is a voltage amplifier which, besides providing considerable amplification, serves to isolate the following tube, a full-wave diode rectifier, from the program line. Such isolation is necessary in order to guard against the possible introduction of distortion on the program circuit.

A voltage, proportional to the amplitude of the program input level, is developed across an adjustable diode load resistor, $R_s$ to $R_l$, which is shunted by a fixed condenser, $C$. The time constant of this $RC$ circuit determines the time delay of the alarm, consequently the load resistor has been made adjustable in steps (by means of a selector switch) in order to provide various time delays. Five time constants, giving delays of 10, 20, 30, 40 and 55 seconds, have been incorporated in the device. Obviously, if desired, the

Circuit diagram of program failure alarm. Variation in the time delay before the alarm operates is provided by the adjustable diode load resistor and condenser.

July 1939 — ELECTRONICS
delay control could be made continuously variable by employing a variable resistor in place of the five fixed resistors.

The grid circuit of the relay control tube is connected across the time delay network. The grid of the control tube is biased, with no input to the device, to a point where approximately 2 ma of plate current flows. When audio input is applied, the voltage across the RC network reduces the negative bias on this tube and the plate current increases through the control tube and the alarm relay. When correctly adjusted, this plate current will reach a value of 20 ma on normal program peaks. This increased plate current actuates the relay and as long as audio input to the device is maintained, the relay remains energized. As is evident from the figure, the relay contacts are open when the relay coil is energized. Thus as long as the audio input is maintained, the alarm does not operate.

When the program input ceases, the condenser discharges slowly through the diode load resistor and the plate current of the relay control tube gradually decreases until it reaches a value of approximately 5 ma. At this point, the relay is released and the alarm operated. The alarm consists of a large red light and an a-c operated buzzer which has no sparking contacts to cause inductive interference in adjacent equipment.

A particularly important feature of the device is the fact that a tube failure or a filament- or plate-voltage failure within the device itself will operate the alarm. Thus, the device monitors its own operation and can not become defective in operation without indicating the failure by means of an alarm.

The CBS Program Failure Alarm is completely a-c operated with self contained power supply. To permit mounting the units on a standard relay rack, they are built on standard 5½ by 19 inch duraluminum panels. Terminals are provided on the rear of the unit for audio input and for external visual indicator, if one is desired. The input impedance is 20,000 ohms so that the device may be bridged across existing program circuits.

Adjustment for Proper Operation

In order to obtain the correct time delay, upon initial installation, it is necessary to properly adjust the input circuit gain control. This is done by applying a test tone at normal program level to the line across which the alarm is connected. A milliammeter is then plugged into the jack in the relay circuit and the current adjusted to 20 ma by means of the gain control on the front panel.

The unit described was designed to operate on lines carrying a level of +8 vu or higher. If a unit is required for protection of a line carrying a lower volume level, an additional stage of amplification should be used. The time constants which have been given are based on tone input but it will be found that they hold quite accurately on program material where there are the usual 100 per cent peaks.

The alarm will operate if the level in the line falls to a value 20 db below the normal transmission level and remains at that level, or lower, for a length of time corresponding to the setting of the delay control. However, the alarm will immediately be turned off when the level rises to a value 12 db below the normal level. The Program Failure Alarm was designed to operate on 60 cycle, 115 volt lines. Changes in line voltage of ±10 volts affect the time constant less than ±1 second.

The unit illustrated above was used on an experimental basis for several months and found to be entirely satisfactory for the purpose in hand. It represents a specific application of several ideas, already disclosed on a broad basis, to a particular problem.
Lagoon of Nations Sound System

In the Lagoon of Nations at the New York World's Fair is a spectacular display making use of water, fire, smoke, light and sound. Each evening just after dusk a pre-arranged show is given. Numerous streams of water, 1400 in number, are projected high into the air and are illuminated by many varicolored floodlights. At times large sheets of flame, dense masses of smoke and various kinds of fireworks join in the visual chorus. The entire performance is accompanied by a musical score.

To maintain a common center of interest, the music must emanate from the center of the fountain. Obviously, an orchestra could not be located there and would not have the volume necessary to overcome the high noise level caused by the 1400 water nozzles, gas jets and fireworks and to cover the large crowds which witness this spectacle. So it was necessary to place several sound projector units near the center of the fountain and to design a high quality sound system of great enough power to cover adequately an audience of 100,000 people at an average distance of 250 feet.

A specially designed high quality sound system was installed to transmit the music from a remote studio to the center of the fountain where it is radiated to the audience with 360 degree acoustic perspective and stereophonic distribution. Two Western Electric Cardiod microphones pick up the music, one for the right aspect of the orchestra and one for the left aspect. Each aspect has a separate channel up to and including the sound projectors. The sound is transmitted by means of special telephone lines, equalized to 11,000 cps, from the studio to the control room on top of the Roumanian Pavilion overlooking the lagoon. Each aspect is fed into a pair of 500 watt Bludworth amplifiers and then through 500 ohm lines to the appropriate sound projectors in the center of the lagoon. A total power of two kilowatts is fed into the speakers. This is great enough to overcome the very high noise level and to cover the large audience properly. The frequency range of the entire system is from 28 to 15,000 cps within two db and with less than three per cent distortion.

Four fireproof sound projector chambers or "igloos", each 24 feet in diameter and seven feet high, are located near the center of the lagoon in the midst of the water nozzles and gas jets. The major axis of the igloo is 700 feet long and the minor axis is 400 feet long. The igloos are 130 feet apart on the major axis and 66 feet apart on the minor axis. There are two low frequency and four high frequency sound projectors in each igloo. The low frequency units are Cinaudagraph 27-inch-diameter cone loud speakers with divided exponential acoustic couplers which are of such dimensions as to project frequencies as low as 28 cps. The efficiency of these couplers is estimated to be about 65 per cent at 30 cps. The high frequency units are Western Electric No. 594A loudspeakers driving Western Electric No. 26A multi-cellular acoustic couplers. There are two high frequency loudspeaker units driving each coupler.

Because of the limitations of the sound projection units, the audible spectrum of 28 to 15,000 cps is divided into two parts at about 250 cps. The lower portion is radiated by the low frequency unit and the higher portion by the high frequency unit. The filters for dividing the spectrum are located between the voltage amplifier and the power amplifiers as shown in the block diagram. Separate 250 watt amplifiers feed the low and high frequency units of each igloo. The characteristics of the filters are such that

![Circuit diagram of amplifier system. Each of four sound projectors is fed by a separate group of amplifiers.](https://example.com/circuit_diagram.png)
they are complementary to the characteristics of the sound projectors with the result that the response over the transition range is flat within one db.

**Stereophonic Perspective**

This is the first known installation of 360 degree acoustic perspective and stereophonic distribution. Such distribution of sound creates in the mind of the listener a very strong illusion of the orchestra being spread out before him, but hidden by the streams of water. Instead of coming from a point source, the music seems to come from an area and the listener is able to determine the location of the individual instruments in the orchestra. To obtain stereophonic distribution, the sound projectors are diagonally paired as to the aspect of the orchestra radiated, that is, on either side of the lagoon, the right aspect is on the listeners right and the left aspect on his left. But on the ends of the lagoon, the perspective is reversed and the right aspect is on the listeners left and the left aspect on his right. However, this effect takes place so gradually as a person walks around the lagoon that it is unnoticeable. Also, the effect is unnoticed by a listener at the end of the lagoon unless he is familiar with the layout of the orchestra.

There are several unique features of the Cinadagraphe low frequency electrodynamic speaker, which is the largest of its kind ever made. It is capable of handling 125 watts of audio power under adverse conditions of moisture. The 27 inch paper cone is made by the flotation process and is water repellant to withstand the effects of continual wetting. The cone is of varying thickness being thickest at the center and becomes thinner in several steps towards the edge. The voice coil is six inches in diameter and one-half inch long, with the coil form one and three-sixteenths inches long. The long form is necessitated by the long excursions required to radiate extremely low frequencies at high amplitudes. The magnetic flux density in the magnetic gap is 21,000 lines per sq cm which is about ten times higher than that used in conventional loudspeakers. This high flux density requires the use of special alloys in the magnet and very careful proportioning of the gap to keep the losses at a minimum. The gap is of such length that the voice coil does not leave the uniform portion of the magnetic field in its greatest excursions. The speaker has a good response up to about 7000 cps.

The installation comprises two separate and distinct sound systems, one for the right aspect and one for the left aspect. Each sound chamber has its own group of amplifiers, one voltage amplifier and two 250 watt amplifiers, one each for the high and low portions of the spectrum. The power amplifiers are all capable of covering the complete range of frequencies in the interests of complete flexibility of operation. The amplifiers operate in Class B and have a total harmonic distortion of less than 1.4 per cent at any volume. The odd harmonics are cancelled out in the cathode circuit of the 6F5 of the voltage amplifier by means of a feedback connection from the plate return of the following tube to the cathode of the 6F5 with the bias voltage kept constant with a voltage regulator tube, VR150. The cores of the interstage, output and impedance matching transformers (by American Transistor) are of hypernic, a special high permeability steel. The total insertion loss of the output transformer, 500 ohm line and impedance matching transformer is less than one db at 30 cps.

Each channel has its own gain control and power level meters. In addition to the power level meters, each power amplifier has its own peak power level indicator in the form of a small neon lamp which is set to glow when the power level is just under 250 watts. This is provided because the meters have too much lag to indicate instantaneous peaks such as given by percussion instruments. The neon lamps permit the amplifiers to be operated at peak power with the definite knowledge that they are not being overloaded.

The four 500 watt amplifiers and associated power supplies are contained in nine racks, each 24 inches wide and seven feet high. The total weight is approximately seven tons. Included in the equipment are a Hammond organ, a carillon, a duplex turn-table for recorded music, and a radio receiver. The sound system is used for incidental music and special announcements during the day, in addition to its use during the regular Lagoon of Nations display.

—C.W.

The sound project system shown below has a frequency range from 28 to 15,000 cps
A COMPACT REMOTE

THE following article is presented in the interests of smaller and more portable remote amplifiers. It is a description of an amplifier designed and constructed here at WHP to meet conditions sometimes found on remote pickups, where space is at an absolute minimum. The ultimate object in view when design was started was to build as small an amplifier as possible, and while some few minor refinements had to be sacrificed in the attempt, certain standards had to be met. The finished product must be portable in the extreme, both as regards weight and size. It must be contained in a single unit, since the presence of a battery box in addition to the amplifier would greatly reduce the ease with which the unit could be transported and set up. Alternating-current operation was immediately ruled out, since experience has shown that there are numerous remote programs occurring in places where the most troublesome job is finding a source of 110 volts ac which may be considered reliable. Also, where a-c operation is used near switchboards etc., as are found in backstage theatre pickups, a good ground is often invaluable in reducing hum pickup. With battery-operated amplifiers, these worries are over. The type and number of microphones to be used next came under consideration. It was decided to use the high impedance type, since this would eliminate the usual input transformer, which adds weight and takes up a large proportion of the available space. The tendency in modern remote amplifiers seems to be more and more toward three and four microphones, but it was decided that sufficient versatility could be obtained with two, and the addition of more channels would defeat the original purpose of the unit, i.e., compactness.

The choice of batteries was determined largely by the types available and the voltage required. Several power output pentodes were found that would operate very nicely at the required output level with a plate potential of only 135 volts. Thus, the batteries used were of the extremely small, portable type. A single 3-volt battery was used for filament supply and a small dropping resistor employed to provide the necessary voltage drop. The four batteries, placed side by side, fit snugly across the chassis as shown in the accompanying photograph. The life of these batteries has not yet been determined. Their initial cost, however, is quite reasonable, and replacement costs in this particular unit will not be appreciable, since the amplifier is used only on occasions when lightness and great portability are demanded.

The choice of tubes for the unit was the next step in design, and resulted in the use of 1J6G mixer, a 1D5G resistance coupled amplifier, and a 1F5G output pentode. The 1J6G is a triode, intended originally for use as a Class B power amplifier, but after experimenting with it as a Class A voltage amplifier at extremely low levels, it was found to be satisfactory for that class of service. It is used as a mixer tube directly following the microphone. Mixing is accomplished in the plate circuits of the 1J6G by the use of 500,000 ohm potentiometers as shown in the circuit diagram. Since the voltage amplification of this tube is rather small when used as a Class A amplifier, it was deemed wise to follow this stage with a high-gain pentode stage. The 1D5G was used in this position, and resistance-coupled to a 1F5G pentode-connected in the output stage.

Since the batteries are not of the heavy-duty type, and it was decided that a frequent check on their condition was advisable, the scrape indicator was made up from a 0-1 milliammeter, using a small copper-oxide rectifier. This permitted the meter to be switched, by means of a three-
AMPLIFIER

By

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In the interests of portability, only two high-impedance microphone channels are used and the usual transformers which occupy much of the space are eliminated.

By the use of a 0.1 millimeter with a CuO rectifier and a three-way switch (top, above), it is possible to check the output level, the A voltage or the B voltage at any time.

Position switch, to read either A voltage, B voltage, or output level. This makes possible the checking of batteries even during the program, and has proven to be one of the most convenient features of this particular amplifier. The effect of shunting the copper-oxide rectifier with its associated condenser and resistor across the output has proved to be not seriously detrimental to the frequency characteristic of the unit. It causes a drop in level of approximately 1.7 db at 8000 cycles, and less than this at 70 cycles. The damping characteristics of the needle on this meter are not ideal, but are considerably better than one would expect. The remainder of the circuit is quite conventional and no unusual features are found. The usual terminations are provided for monitoring headset, lines, and microphones.

As to actual size, the entire unit was built in a standard chassis 12 x 7 x 3 inches. A hinged cover on the rear makes the tubes, batteries, and faders easily accessible. The photograph clearly shows the position of the batteries, and the accessibility of parts for maintenance, even though extreme compactness has been maintained.

The performance of the unit is quite satisfactory for the purpose for which it was built. The frequency characteristic is within 2.0 db from 70 to 8000 cycles. Distortion was measured at one frequency only, due to lack of equipment for spot measurements, and the r.m.s. sum at 400 cycles with zero level output (6 mw) was 2.08 per cent. The output is easily plus 8 db maximum, at normal voice level. Since general practice here is to feed zero level through a 4 db pad to a 500 ohm line, plenty of room is provided on the faders for the rather large dynamic range of volume found on some types of pickups.

As was mentioned at the beginning of this article, some things have been sacrificed in order to obtain minimum size and weight. The symmetry of the front panel is poor due to the necessity of placing units where they would fit best, and not where they would look best on the front panel. A master fader has been omitted, but does not, we think, seriously affect the flexibility of operation of the unit. The frequency and distortion characteristics, while not up to the standards usually expected in a studio type amplifier, or even in a remote amplifier that might be used for symphony or similar broadcasts, are quite good. In some tests, this unit was used side by side with a remote amplifier having frequency characteristics as good if not better than most commercial units. The two amplifiers were switched, and the resulting slightly noticeable change in quality was attributed to the different microphones used, and not to any overall characteristics of the amplifier itself. Otherwise, the unit meets all requirements, and seems well adapted to jobs requiring a minimum amount of equipment, and those occasions do occur at the average radio station.

ELECTRONICS — July 1939
Coaxial Cable Installation

For broadcast engineers who intend installing coaxial lines, or who have trouble with their present installation, Mr. Epperson’s practical review of coaxial problems and procedures has much to offer. The first of two parts

By J. B. EPPERSO
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CONCENTRIC transmission lines have provided subject matter for much published material concerning their characteristic impedance, loss per unit length, necessity for proper impedance matching, and so on. Little if any material, however, has appeared regarding the failures of concentric lines in practice and regarding the installation procedure for such lines. This paper is being presented with the idea in mind that most failures of concentric lines are caused by faulty installation. It is believed that with proper care in the initial installation of such lines and with proper consideration given to their protection from lightning and static discharges, trouble-free operation may be obtained. Reference to the use of concentric lines in this article is confined to those which serve as a connecting length between a radio transmitter and its antenna system.

Concentric Line Failures

In September 1938 the writer prepared a concentric line questionnaire, copies of which were mailed to 90 broadcast stations believed to be using concentric lines and returns were based on 61 replies.

Forty-nine stations had lost no time off the air due to defective lines while 12 stations reported one or more failures. The cause of line failure for the 12 stations was given as follows: Faulty installation, six; faulty installation and/or lightning, five; lightning, one. Four of the five stations checking both faulty installation and lightning as the cause of their difficulties used no power interruption circuits or other means for satisfactorily protecting the line from lightning and static discharges. One of the twelve stations reporting failures employed a shunt fed radiator while the other eleven stations used series feed to their antennas. Six of the failures occurred on underground lines, five on surface installations and one occurred on a line partly underground and partly on the surface. Nine stations used gas filled lines while three operated their lines at atmospheric pressure.

In June, 1937, the Columbia Broadcasting System made a survey of its member stations to determine to what extent failures on concentric lines had occurred. The results of this survey, which were furnished for use in this article by Mr. William B. Lodge, Engineer-in-chief of the Radio Frequency Department of CBS, are as follows: Out of 26 CBS stations of 1000 watts or more power which were using concentric lines, 9 stations had experienced one or more failures. This summary further showed that faulty construction or lightning, or both, caused the difficulties.

From the replies to the questionnaire it was found that ½ inch line

Fig. 1—Section of Isolantite coaxial cable. The shape of the insulator serves to distribute the lines of force uniformly over its surface

Fig. 2—Typical solder-couplings for use with Isolantite cable. Left to right, gas-tight seals, right-angle coupling, gas fitting, couplings for straight runs (1¾-inch and 4-inch lengths). The center conductor is coupled by the small member shown between the outer couplings.

July 1939 — ELECTRONICS
is the most popular size for carrier powers of 5 kw and below. Some of the lower powered stations use the \( \frac{3}{8} \) inch line because of the additional safety factor provided through its use. Others plan in advance to increase their power and consider it an economical move to install a line of sufficient rating to meet future needs.

Neglecting dielectric losses, the conductor losses for different sized lines having the same characteristic impedance will vary inversely with the line diameters. Also, for a given line, these losses will increase directly as the square root of the frequency. These relations should be borne in mind when deciding the size line to use for a given power output and frequency. At standard broadcast frequencies the losses are so small that they can usually be neglected. On the ultra high frequencies, however, it is often a requirement that the cable losses be reduced to a minimum due to the low power used and to the relatively high losses at these frequencies. Some police stations, for instance, which are in operation on the ultra high frequencies use as little as 15 to 20 watts power. While the smallest line available would probably handle this output, noticeable gains in signal strength will be realized if a larger line is used.

Assembly of Coaxial Lines

Most lines up to \( \frac{3}{8} \) inch in diameter are constructed of soft copper and are therefore semi-flexible. Installation of this type line is a very simple procedure since it may be readily bent for changing direction. It is shipped in continuous lengths up to 500 feet and a special solder coupling is used for joining sections when required. Solder couplings are also available for sealing the ends and for admitting gas. Figure 3 shows a section of \( \frac{3}{8} \) inch coaxial cable as placed on a reel for shipping.

The larger sizes of lines are usually shipped in 20 foot or 10 foot straight sections and the conductors are of hard copper. With this type line, "Streamline" solder fittings are in universal use for connecting sections of pipe, for connecting right angle junction boxes, for end seal attachments and for gas fitting accessories. For those who are not familiar with these fittings the following information will be of interest:

Streamline Solder Couplings

The Streamline solder coupling was first introduced by the Mueller Brass Co., of Port Huron, Mich., which now licenses several manufacturers for its use. Tests anticipating service conditions were instituted and worked out for a number of years before this fitting was placed on the market. In the tests, two \( \frac{3}{8} \) inch sections of copper pipe with wall thickness of .065 inches were connected with a \( \frac{3}{8} \) inch solder coupling and pulled in the Olsen
testing machine. It was found that a tension of approximately nine thousand pound per square inch was required to fracture the pipe while the joint itself invariably remained intact. In other words the joint was shown to be stronger than the pipe itself. Tests for the effect of heat, pressure and underground use in various soils are continuously under way. The manufacturers report that they have never had a case of failure of the joint where it was installed properly.

Figure 4 shows a sectional view of this solder fitting. It is a radical departure from methods previously used for connecting pipe in that the joint is made by soldering rather than by threading or flaring. The soldering operation is made by feeding wire or stick solder through a feed hole in the fitting after the copper pipe has been assembled in it and sufficient heat applied with a blow torch. The liquefied solder is carried around the entire surface between the pipe and fitting by the phenomenon of capillary attraction, and becomes visible as a bright line at the outer edge between the pipe and fitting, thus affording visual evidence that a leakproof, bonded joint has been completed. The distance to which the pipe may be inserted in the fitting is made positive by a shoulder in the fitting itself against which the pipe rests. This shoulder is approximately the same height as the thickness of the pipe wall thus insuring a continuously smooth internal surface. Those who are not familiar with the installation of streamline fittings erroneously conclude that the solder feed hole must be located at the top of the fitting. However, the solder will flow up, down, or laterally with equal facility, and the operator can just as readily make a perfect joint by applying the solder through the feed hole located at the bottom or side as he can if it is located at the top. The 3 inch and most larger size lines are installed with special fittings which employ streamline soldered joints throughout. Figure 2 shows some of the isolantite line of solder fittings in which the solder feed holes are plainly visible. Figure 5 shows concentric line and accessories manufactured by Heintz and Kaufman. The fittings shown by Isolantite and Heintz & Kaufman are similar to those manufactured by other companies.

General Installation Instructions

The tools needed for installation are: blow torch, file (10 inch mill half round), hack saw (32 tooth blade), medium No. 1 sandcloth or sandpaper, streamline solder and solder flux or equivalent, solder flux brush. The procedure for making joints in the outer conductor is as follows:

1. Cut pipe square with fine hack saw; remove bur.
2. Using sandcloth or sandpaper, clean outside end of copper pipe equal to depth of fitting. Leave no dark spots. See that all fittings are removed from inside of pipe.
3. Using sandcloth or sandpaper, thoroughly clean inside of fitting where pipe is to be inserted until a bright surface is obtained. Clean feed hole.
4. Apply a coat of soldering flux to outside of pipe and to inside of fitting. Be sure that the flux is distributed evenly. Make certain that there is some flux in feed hole also. In extremely cold weather warm fitting slightly with torch to approximate room temperature.
5. Slip pipe into fitting until it will go no further and turn back and forth once or twice to further insure an equal distribution of the flux.
6. Use pure solder consisting of 50 percent lead and 50 percent tin. Do not use a flux core solder.
7. Using a blow torch or gas tip, melt a drop of solder into the solder feed hole. Apply heat around the fitting until drop of solder disappears, indicating that the proper temperature has been reached. Where the feed hole is located at the side or bottom, the proper temperature may be ascertained by touching the heated fitting with the end of the solder wire (preferably at
the feed hole). When solder melts upon contact, the proper temperature has been reached. Feed solder through feed hole only until solder appears around the end of the fitting for the full pipe circumference. Remove the flame a second or two later and as the connection starts to cool, completely fill feed hole with solder and remove surplus with a small piece of cloth. Bonding the surfaces and filling the hole should be done completely in one heating operation. It is advisable to move the fitting on the tubing or tap with hammer when the solder starts in, thus breaking the surface tension and insuring equal distribution.

The procedure for making joints on the inner conductor is similar:

1. Cut tubing square with fine hack saw; remove bur.
2. Clean connector and inside of inner conductor until a bright surface is obtained.
3. Apply a thin film of soldering flux to the connector; insert it half way into one inner conductor section and solder in place with a small flame.
4. Insert protruding half of connector into other section of inner conductor to be joined, heat with a small flame and solder. Wipe off any excess solder before it hardens.

Installation should start at one end of the line and proceed toward the other. This avoids the difficulty of making a junction in the middle of the line. Cut off about six inches from the outer conductor of the first section of line so that the inner conductor protrudes by this amount. This facilitates installation by caus-

ing an offset between the joints of the inner and outer conductors. Following the instruction procedure for making joints, the inner conductor connector should be inserted half way into the inner conductor of section 1 and soldered in place. With the outside coupling slipped over the outer conductor of section 1, the inner conductor of section 2 is slipped over the half of the coupling pin protruding from the inner conductor of section 1 and soldered. Make sure that the adjacent inside conductors are firmly butted together and that all excess solder is wiped off. Then butt the outer conductors of section 1 and 2 together within the coupling sleeve and solder. If the procedure for making joints in the outer and inner conductor were followed closely, a gas tight joint should result. The remaining copper line is obtained and the bend carefully made. Rather than use soft tubing for making the bends, however, it is more practical to obtain the bends from the manufacturer of the line. Bends may be obtained on any degree of turn on a 14 inch radius.

Two methods of making right angle bends are shown in Fig. 2, including a special tee with a screw plug and a right angle junction box with a solder cover. It is recommended that the tee type bend not be used. It is very difficult to get a small iron in to this type bend for making a satisfactory soldered splice of the two branches of the inner conductors. Even when this has been done satisfactorily, the spacing is so close that a small amount of expansion may cause a short circuit between the inner conductor connector and the end of the "tee." The right angle bend was designed to overcome these difficulties. Figure 10 shows a similar type right angle junction box as manufactured by Victor J. Andrew. These two junction boxes are typical of those available from other manufacturers.

To assemble the right angle bend, cut the transmission line so that the inside conductors extend 2 inches beyond the outside conductors with insulators located as near as possible to the ends of the outside conductors. After the outer conductor joints have been completed, the inner conductors are completed with a rigid or flexible right angle connector as desired. If both branches of the line are horizontal, a flexible connector may be used to take care of the differential expansion. If the line is vertical one way, a rigid right angle connector should be used to offer support to the inner conductor.

(Making Bends in the Line

The ½ inch line may be bent to a radius of approximately 15 inches if a length of special soft drawn

ELECTRONICS — July 1939
NEW BOOKS

Alternating Current Bridge Methods
By B. Hague, University of Glasgow.

In preparing the fourth edition of Dr. Hague's important treatise on electrical bridge methods, the author states that three objects have been kept in view: (1) to insert the substance of former editions into its proper place in the text, (2) to give an account of the developments up to the end of 1937, and (3) to deal with certain matters which experience has shown to be in need of further explanation. The result has been a much enlarged and more fully illustrated volume than the last edition, published six years ago. About 150 pages of new material has been added and the present edition presents a much more logical and systematic treatment than former editions. New material which has been added includes a discussion of the circuit locus diagrams to explain their use in illustrating sensitivity and balance of convergence of bridge networks. A complete classification of bridge networks has been included and additions have been made to the theory of bridge circuits containing mutual inductance in one arm.

As in former editions, this one is concerned with the measurement of inductance, capacitance, effective resistance, and frequency at low and audio frequencies. The author states quite briefly that "radio frequency bridges fall outside of the declared scope of this book", although much of the material presented is directly applicable to bridge measurements at audio frequencies.

The first chapter deals with the fundamentals of bridge measuring networks and includes a historical outline of the development of bridge methods. A general discussion is given of capacitance, inductance, and effective resistance as a basis for further treatment of these components as bridge arm constituents. The second chapter deals with the theory of alternating currents, particularly with reference to its application in a-c bridge networks. The general theory of such networks is derived as a basis for later treatment in which specific forms of bridge networks are discussed. Much of the chapter can very well stand on its own feet as good general a-c theory totally aside from its application to bridges.

The third chapter discusses bridge apparatus and presents an excellent discussion of the desirable characteristics and design data for component parts and standards for bridgearms. This discussion of the properties of standards of L, C, and R will be valuable to any laboratory worker, whether or not he is mainly concerned with bridge measurements. The classification of networks with respect to the way they are built up is thoroughly treated in chapter four, and the student is shown the various possible electrical relationships between the structure of the various arms. The treatment employed is so advantageous to the engineer for it enables him to select the type of bridge most suitable for a given purpose. Chapter five contains a discussion of the choice of networks and establishes the precautions which should be observed in making bridge measurements.

The book is advanced and the reading is mathematical and not particularly easy, although it is lucid and clear. For the well-trained worker in the electrical laboratory who desires a thorough, up-to-date, authoritative treatise on bridge networks and measurements, this volume is heartily recommended. As this reviewer sees it, the only difficulty with the book is the rather high price it bears for the American market.—B.D.

Electric Circuits and Wave Filters

The Second Edition of this well-known British treatise on filter theory has been enlarged by 100 pages, and includes developments which have come to light since the first publication in 1934. The book should serve principally as a reference for research workers, since its compactness of presentation and lack of illustrative problems would make it very difficult reading for the student.

The book begins by laying down the basic mathematical processes underlying filter theory, and while this order is logical it is somewhat disquieting to the reader as he wades into the subject at once. For this reason, the mathematics might better be included in an appendix, especially since the mathematical knowledge must largely be presupposed in any event. Following the introductory chapter, alternating current theory is taken up, followed by a description of the electric circuit and its theorems. The discussion of filter theory proper begins in Chapters V and VI which discuss two-terminal and four-terminal impedances respectively. The remainder of the book is concerned with various forms of wave filters, including the low-pass, high-pass and band-pass forms.

The principal fault with the book is the fact that it maintains a "non-numerical" attitude, stating the results in general algebraic form only. While this generality is an advantage to the specialist who thoroughly understands the subject, it tends to become non-communicative to the reader who desires a working knowledge of the magnitudes involved in filter work.—D.G.F.

Introduction to Contemporary Physics

Readers of The Bell System Technical Journal are familiar with the series of articles on contemporary physics which Dr. Darrow has been writing for many years (the latest in the series is numbered thirty-two). There is perhaps no man writing who has a better command of scientific English and a broader grasp of the significance of modern advances in atomic physics. The present book is a second edition of an earlier work which appeared in 1926. Since that time, as the author states, the "body of recorded phenomena" has increased immensely, the theories, in all branches except nuclear physics, seem to be stabilized, and the whole concept of the wave-particle dualism has been clarified.

It is therefore good time for a thoughtful review of what the physicists believe to be the truth, and Dr. Darrow has accomplished this job in a manner which will disappoint none of his many readers. The book is devoted almost entirely to microscopic physics, and as such is highly recommended to readers of Electronics who wish to know the present status of the elementary particles on which the science is based. The presentation comes as near being a work of art as a book on physics can be.

The subjects covered include: The Fundamental Charge, Electrons, Ions and Isotopes, The Elements, Correlation of Waves and Corpuscles, Diffraction of Waves by Crystals; Infrared Analyses of Spectra, Bohr's Atom, Wave-Mechanics, Magnetism and Electron Spin, Transmutation, Neutrons, and Nuclear Instability. The mathematical treatment is in the main in the manner of word descriptions, and need deter no one from reading the book. No attempt has been made to over-simplify the presentation; its simplicity resides in judicious choice of words and orderly presentation.—D.G.F.

July 1939 — ELECTRONICS
ANTENNA RADIATION CHART

By L. J. GIACOLETTO
For several years, radio engineers have occupied themselves with the problem of predicting the strength of the electromagnetic field at a given distance from an antenna. If a perfectly conducting plane earth is considered, the Hertzian expression for the electromagnetic field produced at a distance, R, is:

$$E_o = \frac{K \cdot P}{R} \quad \text{(1)}$$

where $K$ is a factor depending on the antenna design. For a quarter-wavelength vertical antenna, $K$ is 6.14 if $E_o$ is in millivolts/meter (mv/m), $P$ in watts, and $R$ in miles. Equation (1) then becomes:

$$E_o = \frac{6.14 \cdot P}{R} \quad \text{(2)}$$

The antenna radiation chart printed on the reverse side is a plot in triangular logarithmic coordinates of the basic relationship given in Equation (2).

Effort has been made to cover the range most used in practice. Range extension can be most easily effected by multiplying by powers of 10. Thus if $P$ is extended by a modulus of 100, and $R$ by a modulus of 10, the $E_o$ scale remains unchanged.

The value of $K$ in Equation (1) is dependent on the antenna height and for antenna heights other than one-quarter wave, correction of the radiation chart can be made. For antenna heights of less than one-quarter wave, $K$ is very closely 5.9, or the value of $E_o$ found on the radiation chart to be multiplied by 0.96; for one-half wavelength antenna, $K$ is 7.45, or $E_o$ from the chart to be multiplied by 1.213; for 0.625 wavelength antenna, $K$ is maximum equal to 8.6, or $E_o$ from the chart to be multiplied by 1.4 and for heights above 0.625 wavelength, $K$ decreases rapidly.

It is true that equations (1) and (2) hold only for a highly idealized case. However, the more exact treatments of the radiation phenomenon introduce only a correction factor to the Hertzian expression of equation (1). These more exact solutions can be written in the form:

$$E = E_o A \quad \text{(3)}$$

By L. J. GIACOLETTO

where $E_o$ is the field strength as obtained from equation (1) or (2), and $A$ is a correction factor.

In the Austin-Cohen formula, the correction factor is:

$$A_1 = e^{-\frac{0.0054 \cdot \pi}{\lambda^2}} \quad \text{(4)}$$

where $\lambda$ is the natural base (2.72) and $\lambda$ is the operating wavelength in meters. This correction takes care of the increased attenuation due to currents induced in the earth of a wave propagated along the ground.

A more exact form of the correction was given by L. W. Austin in 1926 as:

$$A_1 = e^{-0.142 \frac{\pi}{\lambda^4}} \quad \text{(5)}$$

A. Sommerfeld has considered the case of propagation of a wave over a plane earth of finite conductivity. The results of this investigation are altogether too complicated for practical application. Van der Pol has derived an empirical approximation of Sommerfeld's equations for which $A$ in equation (3) is:

$$A_1 = \frac{2.0 + 0.3 \rho}{2.0 + \rho + 0.6 \rho^2} \quad \text{(6)}$$

where $\rho$ is Sommerfeld's numerical distance given approximately by:

$$\rho = \frac{0.44 \times 10^{16} R}{\sigma} = 0.938 \times 10^{20} \frac{R}{f} \quad \text{(7)}$$

where $\sigma$ is the conductivity of the earth in emu, $\lambda$ is the wave length in meters, $f$ is the frequency in kilocycles, and $R$ is the distance in miles.

Equation (7) gives the numerical distance quite accurately at low frequencies where the impedance of the earth is primarily resistive. At the high frequencies the impedance of the earth is largely capacitive and the numerical distance is given more exactly by:

$$\rho = \frac{0.00505 R}{(\xi + 1) \lambda} \quad \text{(8)}$$

where $\xi$ is the dielectric constant of earth assuming air as unity. For $\rho$ between 5 and 10 a more exact expression for the correction factor is:

$$A_1 = \frac{4 + 5 \rho}{4 - 10 \rho + 10.4 \rho^2} \quad \text{(9)}$$

For $\rho$ greater than 10, the correction factor will be given with sufficient accuracy by:

$$A_1 = \frac{1}{2 \rho} \quad \text{(10)}$$

The Sommerfeld analysis neglects entirely the curvature of the earth, and therefore gives calculated field intensities which are slightly too high.

G. N. Watson has studied the propagation of radio waves over a perfectly conducting spherical earth. In his solution, the factor, $A$, in equation (3) is:

$$A_1 = 0.4554 \frac{0.0054}{\lambda^{1/3}} e^{-\frac{0.0054 \cdot \pi}{\lambda^2}} \quad \text{(11)}$$

Watson's formula does not hold for regions near the transmitter (say within 500 miles), in this region, Sommerfeld's equations will give good results. C. R. Burrows has derived an empirical formula based on Watson's results which will hold up to 8000 miles. In Burrow's formula the correction factor is:

$$A_1 = (1 + 2.2 \rho) + 0.9 Z \quad \text{(12)}$$

where:

$$Z = 0.0564 \frac{R}{\lambda^{1/3}} \quad \text{(13)}$$

The problem of propagation of radio waves over a spherical earth of finite conductivity has been studied, but as yet only approximate curves are available.

It is seen that the basic radiation formula is the Hertzian expression given in equations (1) and (2) and graphed on the radiation chart. To this basic equation is added a correction factor whose value depends on the degree of approximation desired. The formulas do, however, serve a very useful purpose in engineering work and whenever necessary, the computations can be checked with field intensity surveys.

The dielectric constant of soils in the country varies from 5 to about 30 with a good average being 14. The dielectric constant of water is 80.

July 1939 — ELECTRONICS
NEW PRODUCTS by IRC

...Designed for Dependability

For more than 18 years, IRC resistance engineering has been characterized by its new and improved approaches to the old problems of noises, dependability and efficient heat dissipation. The new products announced here offer convincing evidence of still further improvements in these essential characteristics.

50-WATT ALL-METAL RHEOSTAT...Reduces operating temperatures to almost half those obtained with conventional units. Aluminum construction permits operation at full load down to 25% of full rotation, without exceeding the normal temperature rise (140 degrees C.) by more than 30 degrees C. 2½” diameter; depth behind panel 1½”.

B-31 ATTENUATOR, Bridged “T”, Ladder or Potentiometer Type...A 30-step, stud-type Attenuator that is especially suited for low level work. Noise level of approximately 100 D.B. is maintained in actual service. Two clockspring connectors eliminate the conventional collector ring assemblies. IRC Insulated Resistors are used throughout. Beryllium-copper laminated contact operates over beryllium copper contact studs. 2” long, diameter 2½”.

WIRE WOUND POTENTIOMETER (2 Watts)...Simple, yet highly efficient and durable construction characterizes IRC Type W Wire Wound Control or Potentiometer. Its features include clockspring connector, special long-wearing alloy contactor, resistance wire welded to terminal contacts and flexibility of design for special requirements. 1¼” x 9/16”.

NEW SMALL CONTROLS...Midget Controls with the well-known Metallized type resistance element, clockspring connector and other features heretofore found only in IRC Type CS Controls are now available as standard to meet practically any requirement for the smallest units consistent with full dependability and permanently quiet operation. Case diameter, 1-9/64”, depth 33/64”.

CATALOGS of any of these new IRC items now available upon request.

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403 N. Broad St., Phila., Pa. • In Canada, 187 Duchess St., Toronto, Ont.
TUBES AT WORK

A two-tube measuring circuit for determining amplification factor and mutual conductance, and a tube-indicator bridge with a range from 0.1 ohm to 10⁻² ohms

A Method of Measuring Vacuum Tube Coefficients

BY H. S. Polk

In measuring vacuum tube coefficients, care must be taken to eliminate the unbalancing effects of interelectrode and stray wiring capacities. These are most troublesome when the dynamic plate resistance is high. The method to be described has been used with good results, possessing the advantages of simplicity and ease of adjustment.

The conventional circuit for measuring the amplification factor is shown in Fig. 1. The oscillator applies to grid and plate circuits voltages \( IR \) and \( E \), respectively which are in phase opposition. These are varied in magnitude by adjusting \( R \) until a minimum signal in the phones indicate zero ac plate current. Thus

\[
\mu E_o = E_p \cdot \mu IR = IR.
\]

Whence \( \mu = R/IR \).

Ordinarily zero signal cannot be obtained because of the small capacity currents through the grid-to-plate, grid-to-cathode, and plate-to-cathode-tube capacities as well as through stray wiring capacities. The capacitive reactances at 1,000 cycles are very large, of the order of 10 megohms. Hence when considered in series with the low impedance phones, the phase angles of these unbalancing circuits is almost exactly 90° leading. The current which prevents a perfect balance is therefore practically in quadrature ahead of the oscillator voltage and main ac plate current. It may be cancelled out by an equal and opposite quadrature current without interfering with the main in-phase current which is reduced to zero by adjusting \( R \). This is also true of circuits used to measure mutual conductance and plate resistance.

Consider next Fig. 2 which is designed to measure the amplification constant of tube \( A \). Resistors \( R_1 \) and \( R_2 \) perform the same function as before. The headphones of Fig. 1 have been replaced by \( R_s \), the signal voltage across which is applied to the grid of tube \( B \) through the blocking condenser \( C_2 \). This voltage \( E_s \) consists of two components:

\[
E_s = E_1 \sin \omega t + E_2 \sin (\omega t + \theta),
\]

where \( \theta = 90° \)

\( E_1 \) is reduced to zero by proper adjustment of \( R_1 \). \( E_2 \) is due to the unbalancing capacity currents and is to be eliminated from the output.

Tubes \( B \) and \( C \) have their plates connected in push-pull to the primary of the output transformer. Hence to eliminate the \( E_2 \) component from the output, it is only necessary to apply a voltage \( E_2 \sin (\omega t + \theta) \) to the grid of tube \( C \). This is done by adjustment of potentiometer \( P \) and condenser \( C_1 \) as this circuit is designed to make \( N_{IR} >> R \) and therefore to take a current almost in quadrature ahead of the oscillator voltage. The voltage drop across \( R \) may therefore be made equal to \( E_2 \) in magnitude and phase and as the corresponding plate current components flow in opposite directions in the two halves of the primary, \( E_2 \) will be completely eliminated from the output. The headphones can be connected directly to the secondary or the secondary voltage may first be amplified and then fed to the null indicator. To obtain a balance adjustment is made alternately on \( R_1 \) and \( P \), the tone becoming successively weaker until completely eliminated. \( C_1 \) is made variable so that the phase of the balance voltage can be adjusted slightly but for the most part adjustment of \( P \) is sufficient.

A convenient value for \( R_1 \) is 10 ohms which gives \( \mu = R_1 \). The potentiometer \( P \) has a resistance of 500 ohms, \( R_s = 1,000 \) ohms and \( C_1 = 0.0001 \mu F \). max. The current in this circuit will lead the voltage by 89° 56'. The input to tube \( B \) on the other hand is designed to introduce as small a phase angle as possible. \( C_2 = 0.2 \mu F \) and \( R_s = 1 \) megohm, giving a phase angle of 3° at 1,000 cycles. \( R_s = 500 \) ohms. The self-biasing circuit is of the usual type and the values of \( C_3 \) and \( R_2 \) will depend on the particular tubes used. A twin triode such as the 6F8-G will serve well for this purpose.

The same phase correcting circuit may be used in circuits for measuring mutual conductance and in some circuits for measuring dynamic plate resistance. A slight change in the circuit of Fig. 2 will enable it to measure \( Z_{IR} \). A resistor \( R_s \) is connected between \( m \) and \( n \). \( R_1 \) and \( P \) are adjusted and when balance is obtained it may be shown that

\[
z_m = \frac{1 + R_1}{R_1} \frac{R_2}{R_3}.
\]

A Wide Range Wheatstone Bridge

BY JACK AVINS

The use of the vacuum-tube voltmeter for d-c resistance measurements has been largely limited to megohm bridges, although the same factors which make it more suitable for high-resistance bridges also make it desir-
THERE’S AN ISOLANTITE BASE FOR EVERY TYPE OF TUBE

Tubes shown above are representative of the variety of tubes using Isolantite bases as made by the following companies: Eitel-McCollough, Inc.; Hentz & Kaufman; Hygrade Sylvania Corporation; Hytron Corp.; RCA Manufacturing Co., Inc.; Raytheon Manufacturing Co.; Taylor Tubes, Inc.; and Western Electric Company.

For radio or television—receiving or transmitting—Isolantite* tube bases are ideally suited for the exacting requirements of the vacuum tube industry. Leading tube manufacturers make extensive use of Isolantite because of its mechanical strength and precision, low dielectric losses, and resistance to moisture.

And Isolantite is readily adaptable to new requirements. It is used on iconoscopes as successfully as on receiving tubes. That is because Isolantite's manufacturing processes are flexible and economical. New forms can be produced, either in the widely-used Isolantite body or in Iso-Q, a ceramic with still lower losses for use on ultra high frequencies.

Isolantite engineers will be glad to cooperate with you in the design of new tube bases or other ceramic insulators. This is part of the consulting service offered by Isolantite to the radio and television industries—a service made possible by Isolantite's long experience in insulator design, and by constant study of the present and anticipated needs of the industries it serves. For high-efficiency insulators to meet your requirements, consult with Isolantite engineers.

*Registered Trade-name for the products of Isolantite Inc.

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www.americanradiohistory.com
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(1) VARIETY: The CANNON line of Plugs and Receptacles embraces the greatest variety of fittings produced by any manufacturer in the world.

(2) SPECIALIZATION: The manufacture of Multiple Cable Connectors is the primary interest of the Cannon skilled organization—nor a sideline.

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(5) PIONEERS: CANNON Plugs were first in practically every sound studio and were first to pioneer the Aircraft field.

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(9) SERVICE: With a compact, highly-trained organization, personalized service for every client is a reality—with more than 1,000 stock fittings always available—and with any point in America no more than a day and a half from the factory.

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Our illustrated Bulletins contain valuable information and may assist you in solving your "plug problems". Please specify your requirements when requesting Bulletin.

Fig. 1—Basic bridge circuit

condition the resistance of the several arms may vary by more than a million to one and yet the bridge may be operated at optimum sensitivity.

The calculation of the conditions which determine the sensitivity of a voltage-operated bridge is considerably simpler than the corresponding calculation for the case where the indicator draws current. Referring to Fig. 1, A and B represent two of the arms, while R and C represent the two remaining arms. Using the notation of the figure, the potential difference exciting the indicator is equal to

\[ E_o = \frac{R}{R + C} E_o - \frac{A}{A + B} \]  

The factor denoting the sensitivity \( S \) of the bridge can be written as

\[ S = \frac{\Delta E_o}{E_o \left( \frac{\Delta R}{R} \right)} \]  

since this represents the change in voltage applied to the indicator for a fractional unbalance \( \Delta R/R \) per volt applied to the bridge. Evaluating this from the expression (1)

\[ \frac{dE_o}{dR} = \frac{C}{(R + C)} E_o \]

since \( E_o \), \( A \) and \( B \) are constant.

But when the bridge is approximately

July 1939—ELECTRONICS
Among the very first to specialize exclusively in injection molding, ERIE RESISTOR developed and perfected single operation molding of plastic bezels around spherical glass. Now, ERIE RESISTOR again pioneers by adapting a new plastic material, Bakelite Polystyrene, to video i-f and r-f coil forms for RCA-Victor Television receiving sets.

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Wherever economical injection molding of parts is feasible, you can profit by the specialized knowledge and experience of ERIE’S design staff.

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OTHER ERIE PRODUCTS FOR TELEVISION

These condensers provide the high tuning stability with low losses so necessary in television receivers. Temperature coefficient is approximately +.000025, Power Factor .04% at 1 megacycle.

A non-inductive multiple ring composition resistor ideally suited for the dissipation of power at high frequencies and voltages.

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MANUFACTURERS OF RESISTORS • CONDENSERS • MOLDED PLASTICS

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Precise

and

faithful

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of

our

customers' designs is the foundation of our enviable reputation in the ceramic industry.

balanced \( R = rC \), so that, substituting in (2)

\[
S = \frac{\Delta E_a}{E_a} = \frac{r}{(1 + r)^3}
\]

(4)

When \( r >> 1 \)

\[
S = \frac{1}{r}
\]

(5)

Thus for ratios greater than 10:1, the sensitivity of balance varies inversely as the ratio \( r \). For a ratio of 10:1, the sensitivity is \( \frac{1}{10} \) that of the optimum value which obtains for unity ratio. For a ratio of 1,000:1, the sensitivity drops to \( \frac{1}{250} \) of the value for unity ratio.

It will be noted that the sensitivity is entirely independent of the ratio between the upper and lower arms, a factor which is used to advantage in the design of the bridge arms for wide coverage. Obviously the indicator and voltage supply positions are not interchangeable in this type of design.

In accordance with the above principles governing the sensitivity of balance, a standard decade box is used at \( A \) and together with one of several fixed resistors \( B \) forms the two lower arms of the bridge. The unknown \( R \) in conjunction with another one of several fixed resistors forms the two upper arms. To keep the ratio \( r \) near unity, \( B \) should be comparable in value to \( A \). This immediately fixes the value of \( C \), which must of the same order as \( R \). By making \( B \) and \( C \) switch-controlled, this switch can be used to provide a multiplying factor in conjunction with the decade box. The values shown in the Table are such that the bridge ratio is kept close to unity over the entire range; over the range from 1 ohm to 10 megohms the ratio never exceeds 10:1. Since

**Fig. 2**—Complete circuit diagram of bridge
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In return for its welcome in the American home, radio provides millions of dollars worth of entertainment, education, and news which listeners receive free. In addition, radio renders services to the government, churches, universities, farms, ships, airplanes, and business which have an untold value.

How vital these services are is dramatically illustrated in contrasting pre-radio days with the present. For example... just imagine the cost and confusion that would be caused if news of the signing of a peace treaty should take two weeks to travel now from Europe to America as it did in 1815!

RCA's Role in Increasing the Services of Radio!
Research in RCA Laboratories is the basis of the ever-expanding services of the Radio Corporation of America. Research made possible the development of NBC and its two networks, the Red and the Blue. Research creates the extra values offered in RCA Victor Radios, RCA Victor Television Receivers, RCA Victrolas, Victor and Bluebird Records, and all of the sound, radio, and motion picture equipment built by RCA Victor.

All of the activities of RCA are dramatized in the RCA exhibits at the New York World's Fair and at the San Francisco Exposition. We cordially invite you to visit these fascinating exhibits.

Listen to the "Magic key of RCA" every Monday, 8:30 to 9:30 P.M., E. D. S. T., on NBC Blue Network.

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ELECTRONICS — July 1939
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—YOU'LL FIND in
the NEW PRESTO
MODEL Y

NEW 16" TURNTABLE

Completely new rim drive mechanism. Uses no idler wheels. Changes from 36 to 33⅓ rpm. instantaneously.
Shift a lever—cut outside-in or inside-out.

New cutter feed mechanism. Makes eccentric trip groove at finish of record . . . makes starting and running spiral grooves . . . cuts 112 lines per inch. Presto high fidelity cutting head. Range 50 to 6500 cycles.

Cuts record up to 17½" size.

NEW RECORDING AMPLIFIER

Output ten watts—gain 125 db.
Equipped with two-microphone mixer, high and low frequency equalizers, playback volume control, volume indicator, and selector switch for recording and playing records and for public address operation.

LIGHTEST 16" RECORDER
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Turntable mounts in one case weighing 41 lbs. Amplifier and loudspeaker combine in second case weighing 47 lbs.

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ELECTRONICS — July 1939
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higher voltages when measuring high values of resistance. For current to all the arms of the bridge are brought out to separate terminals when the multiplier switch is placed in the "External" position. This makes it possible to extend the range of the bridge, or to substitute other standards. The guard terminal which is also made available can be used in the measurement of three-terminal resistances.

To eliminate the necessity for batteries, the indicator is completely a-c operated. Referring to Fig. 2, it will be noted that a balanced circuit is used in which the cathodes of the two 6K6G tubes are connected together and returned through a 50,000 ohm resistor to a negative point on the power supply. The power supply is conventional and provides the plate voltage of plus 20 volts, the cathode-return voltage of minus 40 volts, and the heater voltage of 5.6 volts. These low operating voltages assure long tube life.

Because of the high value of cathode resistance, an unusually high degree of self regulation is secured. However, this is not accompanied by any appre-
QUANTITY production of television tubes is now under way. Already the large RCA tube plant at Harrison, N. J. is producing both electrostatic and electro-magnetic cathode ray tubes.

Making regular size tubes of 3 inch to 12 inch ...and special sizes on order...RCA is meeting the demands of receiver manufacturers.

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Important among the latter are Nickel and Nickel-base alloys. Possessing unusual combinations of properties, these metals meet the exacting demands of television:

Delicate parts, precision made, must be strong to withstand repeated handling, high temperatures during bombardment, jolts during shipment, and accidental abuse in service. They must also withstand the corrosive effects of moist hands and humid atmospheres. Nickel possesses the necessary properties, and in addition is readily formed, welds easily, and provides strong spot welds. It also offers suitable electron emission characteristics, good electrical conductivity, good thermal conductivity, high melting point and satisfactory thermal expansion.

Just as these unusual properties of Nickel have contributed to RCA's progress in television, so they can help manufacturers in other electronic fields. Write for information.

THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL ST., NEW YORK, N. Y.

ELECTRONICS — July 1939
the New DAVEN Type No. 910
VOLUME LEVEL INDICATOR

It is designed to indicate audio levels in broadcasting, sound recording, and allied fields where precise monitoring is important. The Type 910 unit is completely self-contained, requiring no batteries or external power supply. The indicator is sensitive to low power levels, rugged and dependable.

The indicator used in this panel is the new WESTON Type 30 meter, the dynamic characteristics of which have been approved by BELL TELEPHONE LABORATORIES, N.B.C. and COLUMBIA Engineers. The indicator reads in percent voltage and VU. The "VU" is defined as being numerically equal to the number of DB above 1 mw. reference level into 600 ohms.

Two meter controls are provided, one a small decade with screwdriver adjustment for zero level setting of the meter pointer; the other a constant impedance "T" network for extending the range of the instrument in steps of 2 DB.

Because of the length of the meter scale, small differences in pointer indications are easily noticed. For this reason the screwdriver type vernier is provided. All V.U. meters can thus be adjusted to the same scale reading. This is particularly convenient in complex installations where several V.U. meters must be read by one operator, or in coordinating the various meters at different points in a network.

SPECIFICATIONS

- **Input Impedance:** 5700 ohms constant on all steps of meter range switch except on the 1 mw. calibration step.
- **Power Level Ranges:** Standard 1 mw. at 600 ohms reference. See table below.
- **Frequency Range:** Less than 0.2 Db. variation up to 10,000 cycles.
- **Scale Reading:** Meter calibrated — 20 to 3 VU and 0 to 100%. Type "A" Scale, for sound level work is marked in VU on the upper scale; Type "B" Scale for broadcasting work is marked in percent on the upper scale.
- **Indicating Meter:** Copper-oxide type

<table>
<thead>
<tr>
<th>Type No.</th>
<th>Range</th>
<th>Zero Calibration</th>
<th>Scale</th>
<th>Price</th>
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</thead>
<tbody>
<tr>
<td>910-A</td>
<td>1 mw. = 4 to 10 VU off</td>
<td>1 mw. 600 Ohms A</td>
<td>$72.50</td>
<td></td>
</tr>
<tr>
<td>910-B</td>
<td>1 mw. = 4 to 40 VU off</td>
<td>1 mw. 600 Ohms A</td>
<td>72.50</td>
<td></td>
</tr>
<tr>
<td>910-C</td>
<td>1 mw. = 4 to 24 VU off</td>
<td>1 mw. 600 Ohms A</td>
<td>72.50</td>
<td></td>
</tr>
<tr>
<td>910-D</td>
<td>1 mw. = 4 to 21 VU off</td>
<td>1 mw. 600 Ohms A</td>
<td>72.50</td>
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</tbody>
</table>

The new "T" attenuator illustrated at left is a 12 step unit. Both the 12 and 20 step attenuators are in stock for immediate delivery.

Type T-994 Price $12.50 12 step attenuator

Type TA-1000 Price $17.50 20 step attenuator

Round dial supplied with above attenuator

Type 991 Price $3.00 Rheostat for calibrating meter

The new "T" attenuator illustrated at left is a 12 step unit. Both the 12 and 20 step attenuators are in stock for immediate delivery.

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<td>910-D</td>
<td>1 mw. = 4 to 21 VU off</td>
<td>1 mw. 600 Ohms A</td>
<td>72.50</td>
<td></td>
</tr>
</tbody>
</table>

The new "T" attenuator illustrated at left is a 12 step unit. Both the 12 and 20 step attenuators are in stock for immediate delivery.

Type T-994 Price $12.50 12 step attenuator

Type TA-1000 Price $17.50 20 step attenuator

Round dial supplied with above attenuator

Type 991 Price $3.00 Rheostat for calibrating meter

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These combine to prevent an excessive increase in cathode current and consequently in the current through the voltmeter. At the same time, the grid resistor and condenser form a filter which prevents an indication as the result of stray alternating voltages.

**Leakage Problems**

Because of the extended high resistance of the bridge, care must be taken to prevent stray leakage paths from impairing the accuracy of measurement. Although this may seem somewhat paradoxical at first thought, greatly improved performance can be obtained by using a conductor rather than an insulating panel. Where a metal panel is used, the leakage paths which exist are not between the several junctions of the bridge, but are directly to the guard terminal which is connected to the panel. This is clearly important because of the fact that the vacuum-tube indicator and its associated B-leads are in proximity to the panel, and any leaks between these leads and points in the bridge circuit would produce an error.

As far as the insulation of points 1 and 2 from the panel is concerned, the values of shunt leakage resistance must be high in comparison with 100,000 ohms, the latter being the maximum value of resistance used in the A and B arms. This condition is of course easily satisfied. In this particular the voltage used to supply the bridge must also be carefully insulated from the panel since any leakage to the panel will appear as a shunt resistance across the A and B arms. Again this leakage must be kept to a value high in comparison with 100,000 ohms.

The point at which the insulation must be of the highest quality is at the high terminal of the unknown resistance R. To satisfy this requirement a ceramic insulator which has low surface leakage is used. It will be noted from the photograph that separate insulators are used for the two terminals of R so that these two terminals in conjunction with the panel form a three terminal network in which the leakage to the panel does not affect the accuracy; the only affect of leakage between the high terminal of R and the panel is to slightly lower the sensitivity of balance where high values of resistance are being measured. As long as the leakage resistance between the low terminal of R and the panel is high in comparison with 100,000 ohms the accuracy is not impaired.

**Measurement of High Resistances**

The measurement of resistances above 100 megohms is preferably made by using a 100-megohm standard in the C arm in accordance with the arrangement shown in Fig. 2. An inexpensive and satisfactory standard can be made by placing ten 10-megohm resistors of the metalized type in series. Although this resistor is not so stable as a wirewound standard, it

July 1939 — ELECTRONICS
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BAKELITE PLASTICS HEADQUARTERS

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ELECTRONICS — July 1939

49
The Plastics Department of the General Electric Company announces that it has acquired the equipment and facilities of General Laminated Products, Inc. of New York, which for six years has been distributor and fabricator of G-E Textolite laminated materials.

These manufacturing facilities will be combined with those of the Meriden, Conn., Works of the Plastics Department and from the latter point General Electric will serve its customers in the East directly and with no interruption.

Parts formerly fabricated of fibre by General Laminated will be included as part of General Electric's complete fabricating service.

This change will affect only customers in the East in so far as the ordering of Textolite fabricated parts is concerned. All future orders and inquiries as of this date should be sent to Plastics Department, General Electric Company, Meriden, Conn.

In the Middle West the fabricating and distributing of Textolite laminated will continue to be handled by General Laminated Products, Inc. of Illinois, 3113-23 Carroll Ave., Chicago, Illinois.

If you are not already a user of Textolite laminated materials, find out more about them. You will find a variety of grades in sheet, rod, and tube form to meet every combination of electrical and mechanical properties. You will find General Electric's new fabricating facilities ready to give fast uninterrupted production on your fabricating requirements.

Write to

IN THE EAST
PLASTICS DEPARTMENT, GENERAL ELECTRIC CO., MERIDEN, CONN.

IN THE WEST
GENERAL LAMINATED PRODUCTS, INC.
3113-23 CARROLL AVE., CHICAGO, ILL.

is entirely satisfactory since its exact value can be determined at any time in terms of the more accurate standard resistances used on the lower ranges.

It will be noted that the temperature coefficient of this standard has the same values as its 10-megohm components, while the voltage coefficient is one-tenth that of the 10-megohm components. For precision work these coefficients must be taken into account.

**Measurement of Low Resistances**

Although the measurement of very low resistances requires the use of a Kelvin bridge, careful attention to design makes it possible to extend the lower limit of resistances which can be measured. To reduce errors due to switch-contact resistance, the minimum value of resistance used in the C arm is kept to 1 ohm; this minimum value is used for the measurement of resistances below 1 ohm. Since the switch contact resistance is less than a milliohm, the error from this source will not exceed 0.1%.

Heavy bus bar should be used to connect the low side of R to the battery junction 1 and the high side of R to the indicator junction 3. Alternatively, the need for these heavy leads can be reduced by wiring the indicator to the high terminal post of R, and by wiring one side of the bridge supply voltage directly to the low terminal post of R. Where this arrangement is followed, the internal lead resistances connecting the R arm with the A and C arms appear as part of the A and C arms rather than as part of the resistance being measured. Since the minimum value of resistance ever used in the A and C arms is 10 ohms, these lead resistances do not cause any error provided reasonably heavy wire is used.

A useful feature of the bridge is its ready adaptability for the production checking of resistors. For this purpose the indicator is provided with a 15,000-ohm rheostat which can be preset so that the maximum allowable error will cause a deflection in either direction from the zero to two fixed indices on the meter scale.

**VALUES OF B AND C ARMS**

<table>
<thead>
<tr>
<th>Switch</th>
<th>Range</th>
<th>B-Position</th>
<th>Ohms</th>
<th>C-Position</th>
<th>Ohms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.001-1</td>
<td>100 K</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1-10</td>
<td>100 K</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10-100</td>
<td>100 K</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>100-1000</td>
<td>100 K</td>
<td>1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1 K-10 K</td>
<td>100 K</td>
<td>10</td>
<td>10 K</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>10 K-100 K</td>
<td>100 K</td>
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<tr>
<td>7</td>
<td>100 K-1000 K</td>
<td>100 K</td>
<td>1 M</td>
<td>1 M</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1 M-10 M</td>
<td>10 K</td>
<td>1 M</td>
<td>1 M</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>10 M-100 M</td>
<td>1 K</td>
<td>1 M</td>
<td>1 M</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>100 M-1000 M</td>
<td>100</td>
<td>1 M</td>
<td>1 M</td>
<td></td>
</tr>
<tr>
<td>Ext. 100 M-1000 M</td>
<td>10 K</td>
<td>100 M</td>
<td>1 M</td>
<td>1 M</td>
<td></td>
</tr>
<tr>
<td>Ext. 1000 M-10,000 M</td>
<td>1 K</td>
<td>100 M</td>
<td>1 M</td>
<td>1 M</td>
<td></td>
</tr>
</tbody>
</table>

$K = 1000$  $M = 1,000,000$

July 1939 — ELECTRONICS
NOTHING TAKES THE PLACE OF ELECTRONICS!

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THE ELECTRON ART

Impulse detector in television receivers, negative resistance oscillators, projection kinescopes, mentioned in this month's news

Output Tubes

In an article "Pentode and Tetrode Output Valves" by J. L. H. Jonker, in the June issue of the Wireless Engineer, an attempt has been made by investigating the static and dynamic characteristics of screen grid tubes, to lay down the requirements that the static characteristics of such a tube must fulfill, in order to assure a minimum of distortion in the output under all circumstances.

To meet these requirements, it is necessary to suppress secondary emission and to make the deflection of the electron of the grids as small as possible. The passage of secondary electrons between two electrodes is subjected to close examination, an inquiry being made as to the possibility of preventing this passage of electrons by the use of two methods of suppression: a space charge and a suppressor grid.

The optimum effect is obtained by the cooperation of both of these expedients, the more potent of the two being the suppressor grid. By judicially planning the geometrical positions of the electrode, deflection of the electron paths can be reduced to small magnitude.

Television Transmitter

An article by A. Mallem and G. Rabeteau "The Eiffel Tower Television Transmitter" in the April issue of Electrical Communication gives a 16-page treatment of the radiating system, video and audio equipment, power and water supply, monitoring equipment and antenna which is used at the present time in the television transmitter atop the Eiffel Tower in Paris.

The standards for picture transmission are sufficiently different from those used in the United States so that the transmitter would be unsuitable for American practice, but the article does provide a good general picture of a modern television transmitter having a nominal peak power of 30 kw. An interesting part of this article deals with the performance characteristics of the transmitter, an outline of the measuring equipment, most of which had to be developed, for determining the performance of the transmitter.

The Absolute Ampere

An article by H. L. Curtis, R. W. Curtis, and C. L. Critchfield, "An Absolute Determination of the Ampere Using Improved Coils," appearing in the Journal of Research of the National Bureau of Standards gives the results of a new determination of the absolute value of current as measured by the current balance method. The article gives complete details of the method of measurement, as well as the results of measurements made at a number of national physical laboratories. The results obtained from this new determination indicate that 1 N.B.S. international ampere is equal to 0.99986 absolute ampere.

Reflexed Amplifiers

The subject of reflexed amplifiers is opened by S. J. Watson, in an article "Reflexed Amplifiers," in the Australian A.W.A. Technical Review for January, 1939. Such amplifiers are employed for simultaneously amplifying the intermediate and audio frequencies in superheterodyne receivers, especially where the cost of production and size of the receiver are to be kept low. The requirements of a reflexed amplifier are high gain, low distortion, and small minimum volume.

Measurements of mutual conductance indicate that a maximum gain is obtained for a special value of resistive audio anode load, but in general values of anode load smaller than this special value are required in order to maintain the distortion within tolerable limits. The conclusion is reached that the least distortion and the least "minimum volume defect" are obtained by using the lowest feasible grid bias and adjusting the screen voltage so that the tube operates at the peak of the mutual conductance curve.

In operating a fixed bias reflexed amplifier, conditions of screen and grid voltages should be selected so that the tube operates over the region of the maximum of a mutual conductance curve. For any specified conductance curve the peak is shown to give maximum gain and minimum overall distortion.

The figure of merit or overall gain depends upon the values of each of the anode loads in the plate circuit of the tube, but at an optimum value of resistive load it reaches a maximum independently of the transformer load. This optimum value of resistive load

TELEVISING NOVA-BAER FIGHT

First television program of prize fight occurred June 1 when the Nova-Baer fight was staged at the Yankee Stadium. This photograph, taken during the semi-final bout between Max Marek and Wally Sears shows the television camera at the ringside.

July 1939 — ELECTRONICS
IN THIS single element radio safety core produced by Arthur O. Austin of Barberton, Ohio, a special canvas base Formica tube 3½"x5"x20" is used as the safety core. To each end of the Formica tube is attached a metal collar, one attached to the base of the insulator and the other to the bolt seen at the top. The porcelain tube is placed between the castings with seals at each end and the whole is filled with oil. The Formica has to take a compressive strain of upwards of 40 tons. There is a grade of Formica for every purpose for which materials of the type can be used. Consult our engineers about your insulating problems.

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may be found by means of a simple geometrical relationship.

Low distortion and low minimum volume are associated with operating conditions which employ low screen voltages, low resistive anode loads and high values of mutual conductance. Except in special cases, therefore, a compromise must be made between gain and distortion in the design of a reflected stage.

The reflexed tube, owing to the minimum volume effect, must be followed by a power output valve, and not by an audio driver or preamplifier feeding the power stage.

Radio Slide Rule

A brief description of a slide rule designed specifically for the radio engineer, and manufactured by the Keuffel & Esser Co., is given in the June issue of the Bell Laboratories Record. In addition to the ordinary scale usually provided, the radio slide rule carries the usual L scale with an added dB designation which is used for the conversion of ratios of power, voltage, and current in reference to the D scale. The LC constants for a given frequency, the values of inductance and capacitance to resonate a reactive circuit, and the transformation of vectors from rectangular to polar form or vice versa, may be determined. Scales are also provided to simplify the calculation of propagation of radio waves.

The Impulse Detector in Television

An interesting and straightforward treatment of the television amplifier problem is contained in an article entitled, "Point Detectors Applications to Television" by R. Barthelemy in the October 1938 issue of L'Onde Electrique.

One of the fundamental problems arising in television is to separate the two types of periodic signals in which only the ratio of maximum amplitudes alone is determined, viz; the amplitudes may be variable.

In the case of fixed amplitudes, the solution is simple in that one signal is eliminated by a diode or a suitably polarized tube. If the amplitudes vary then it is necessary to regulate the polarization as a function of these variations. The purpose of the article is therefore designed to show how this regulation may be obtained automatically.

Due to the oscillatory current introduced in the detector circuit, a current i flows to the anode and capacitor C acquires a charge Q according to the relation:

\[ Q = C B i. \]

The oscillatory voltage \( \mu \) is effective in driving current i through the tube only to the extent that its amplitude is superior to the polarizing voltage \( \frac{Q}{C} \) i.e. the portion of voltage \( \mu \) which is of higher amplitude than \( \frac{Q}{C} \) serves to furnish the current i in the detector.
A state of equilibrium is attained after a time and a definite interdependence is found to exist between polarizing voltage \( Q/C \) and the maximum amplitude of \( \mu \).

The quantity of charge lost by the condenser due to discharge through the resistance \( R \) is compensated for by the current \( i \) flowing through the circuit. The equation which determines the relationship is:

\[
\int_{t_1}^{t_2} i dt = \int_{t_1}^{t_2} \frac{Q}{CR} dt \quad (1)
\]

where the limits \( t_1 \) and \( t_2 \) are determined from the wave-shape of the oscillatory voltage \( q \).

Consider the case of a wave-shape such that the time-constant \( CR \) is always large in comparison to the period \( T \) of the voltage \( a \). Thus by

\[
\int_{t_1}^{t_2} i dt = \int_{t_1}^{t_2} \frac{Q}{CR} dt
\]

giving \( CR \) a value equal to \( 20T \) the variation of \( Q/C \) does not exceed 5 percent in the course of a period \( T \) and may be considered constant. The current due to the condenser \( C \) which flows in \( K \) may likewise be considered constant, hence:

\[
\int_{t_1}^{t_2} \frac{Q}{CR} dt = \frac{Q}{CR} T
\]

To simplify matters suppose the detector characteristic to be linear, i.e. in a sense it presents a constant internal resistance \( p \). The circuit impedance for the most part being negligible for the impulse-moments under consideration. The current \( i \) is given by:

\[
i = \frac{Q}{CR} \quad \text{during the interval } t_1 - t_2.
\]

The relation (1) can now be rewritten as:

\[
\int_{t_1}^{t_2} \frac{Q}{CR} dt = \frac{Q}{CR} T
\]

The instants \( t_1 \) and \( t_2 \) are determined by:

\[
t_2 = \frac{Q}{\mu}
\]

\( \mu \) being expressed as a function of \( t \). For a rectangular wave-shaped figure

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**PHOTOELECTRIC CELLS:** Graphite surfaced electrodes absorb free alkalies and alkaline metals in photoelectric cells. No selenium results when the "dag" product is used in the selenium types.

The above statements should not be considered as recommending the use of colloidal graphite in violation of any valid patent which may exist.
or signal of amplitude $U$ as used in television, it is shown that if we desire to eliminate all the signal which is under 90 per cent of the amplitude $U$, the ratio $\frac{R}{p}$ becomes $\frac{3}{90}$. It is therefore desirable to operate with a diode having a low internal resistance in order that $R$ may be kept from being many megohms in value. It should be kept in mind that the value of $R$ thus determined is the suitable minimum value and that although higher values of $R$ will give more assured separation it will simultaneously result in a reduction in useful signal amplitude.

In order to meet the actual transmission conditions which do not possess the idealized properties which were previously imposed for simplicity, it is necessary to make use of a double diode circuit such as shown in Fig. 2.

![Fig 2—Double diode impulse detector circuit](image)

It can be seen that the $R-C$ combination develops a voltage which may be utilized for automatic amplification control. The author illustrates the case for a sinusoidal voltage wherein he shows that for an equivalent amount of protection i.e. for equivalent ratios of $Q/C$ to $U$ the values of $\frac{1}{3}$ in the sinusoidal and the preceding rectangular wave case compare as 13 to 23 respectively. The difference is attributable to the increased time interval in the sinusoidal-wave case. In conclusion the author considers the amplitude control obtainable from a triode by utilizing the lower bend in its characteristic, and points out to what extent the resultant operation may be compared with similar actions in the previously studied diode detector circuit.

**Cathode Ray Tube in Mass Production**

Two examples are discussed in cases in which the cathode ray oscilloscope made it possible to adapt an otherwise rather complicated measurement to the tempo of mass production in an article entitled "Application of Cathode Ray Tube in Mass Production," by H. van Suchtelen in the March issue of the Philips Technical Review. The first application refers to the determination of the resonant curve of radio receiving sets and the second refers to the detection of defects in the winding of motors or dynamo armatures.

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![Image of INSUROK products](image)
Projection Kinescopes

Projection Kinescopes have been the subject of considerable investigation and speculation. Distinguished groups of workers have concentrated on direct magnification of the primary received image. A few have attacked this elusive problem by seeking to apply a signal-modulated secondary image device. An interesting proposal along this second approach has recently appeared by Manfred Van Ardenne in Fernseh-Funk-und Fernsch Technik, 1938 supplement pp. 518-524.

The author, bases his tube design on the experiments of Ch. Schrummm with electron-optic effects in zinc-blende crystals. In the suggested tube a video-modulated beam strikes a crystal screen composed of native zinc sulphide. The electric field produced about this crystal causes the screen’s optical polarizing angle to rotate to a degree dependent on the field strength. A polarized beam which a projection lamp throws on the crystal is thus subjected to further polarization as it passes thru the crystal and produces an enlarged image on a motion picture screen after the beam has passed thru a polarizing filter and a projection lens. The scanned portions of the crystal remain charged until they are blanked out by an auxiliary discharge beam which is in synchronism with the television image beam and is timed to precede it by a short distance.

The storage effect obtainable with the proposed system obviously would permit reductions in line and picture frequency requirements, and would improve flicker.


Electron Tube Corn Popper

Charles Millikan, graduate engineer at the California Institute of Technology, pops corn in a cellulose bag by using short radio waves. The device operates on the same principle as the more common popcorn machine, but employing the electron-magnetic machines, is rather uneconomical when used solely for corn popping.

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Whether your application calls for a standard or special unit — ask Ohmite. The extensive range of stock types in wire wound resistance units found only at Ohmite often gives the quick, dependable, economical solution you seek. Or—the wide experience of Ohmite Engineers in the design of special models for unusual applications in the electronic, radio and industrial fields is at your service to help you get exactly what you need.

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ORTHICON

(Continued from page 11)

Thereafter the beam travels into the tube proper, shown in Fig. 10. A coil surrounding the tube produces a uniform magnetic field whose lines of force are parallel to the axis of the tube. The low-velocity electrons in the beam, when left to their own devices, travel along these lines of force. Deflection is accomplished by superimposing on the magnetic field an electrostatic field between two large deflecting plates. The actions of these deflecting plates is shown in Fig. 8. The deflecting plates impart a transverse motion to the electrons, in the direction of the positive plate. This transverse motion, through the axial magnetic field, causes the electron to describe a path which projected on the end-view resembles a half circle, returning the electron to its original distance from the positive plate. The half-circle motions are repeated and the result, as projected, is a cycloidal motion which displaces the beam to the right as shown. During this motion, the beam is proceeding forward. Consequently when it emerges from the deflecting plates, the beam has been moved sidewise by the width of the cycloidal motion. However, on emerging from the plate, the beam no longer executes the cycloidal motion but takes a path depending on its components of velocity at the instant of leaving the field between the plates. If the electron happens, at this point, to be at the bottommost point of one of cycloids, the path after emerging is a straight line parallel to the axis of the tube.

The cycloidal motion is a means of deflecting a beam without introducing any angular deviation between the beginning and end of the electron motion. While the cycloidal motion is a possible mode of operation it is difficult to control. The cycloidal motion may be modified, as shown by the line (B) in Fig. 8, to a motion which moves directly across the tube. This modification of the cycloidal motion is obtained by using deflection plates with appreciable fringing field at their edges.

The electron is thus introduced into the electric field gradually, and the cycloidal motion gives way to a
straight-line motion across the tube. By means of curving the edges of the deflecting plates, the necessary fringing field is established, and the smooth deflection motion obtained.

A similar type of deflection could conceivably be used for both directions of scanning (vertical as well as horizontal), but it is more convenient to restrict this type of deflection to the high-speed horizontal motion. The low-speed vertical motion may then be introduced by the use of a transverse magnetic field imposed, as shown by Fig. 9, by a pair of magnetic coils whose axis is at right angles to the tube axis. This type of deflection tends to set up helical motions in the beam, but the diameter of the helices is so small that they do not affect the geometry of the scanning pattern or the sharpness of focus.

A diagram of the complete tube is shown in Fig. 10. The internal coating of the tube is grounded, and the cathode of the electron gun is operated at about —25 volts with respect to ground. The two-sided mosaic target at the other end of the tube assumes cathode potential automatically. The horizontal deflecting plates cause the beam to move along each line of the image, while the vertical deflecting coils cause the vertical frame-scanning motion. The electrons travel to the mosaic, and arrive there with substantially no velocity. As one observer put it, the electron "nuzzles" the globules of the target. If photoelectrons have been lost at that point, due to the influence of the optical image, the beam electron is collected by the mosaic, otherwise it turns around and travels back to a collector electrode near the cathode.

The authors of the paper illustrated the results obtainable with it in several lantern slides. One of these, of the toy duck which serves as a studio subject, is reproduced on the cover of this issue. Others showed absence of uneven shading in the background, and freedom from streaking.

The Orthicon is still in the experimental stage, and no plans for its commercial production have as yet been formulated. However, there is no doubt that some time in the future it will be available for use in regularly-scheduled television transmissions.—D. G. F.

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**ELECTRONICS — July 1939**
**The Industry in Review**

**News**

+ Donald M. Simmons, chief engineer of the General Cables Corp., was awarded the honorary degree of Doctor of Engineering by Princeton University. *WTIC*, Hartford, Conn., is getting two new vertical diodes. Directional array will prevent interference with KRLD of Dallas, Tex. Blaw-Knox is doing the job. Willard H. Cobb has been appointed general manager of the Mechanical Goods and General Products division of the United States Rubber Co. NBC has doubled the time of television broadcasts. At least eight of the ten program hours weekly will be presented by live talent. The first television queen was selected at the New York World's Fair. The Universal Microphone Co., Inglewood, Calif., has been granted a license by Western Electric, ERPI and AT&T to cover all microphones manufactured by that company, past, present and future. RCA is popularizing electronics with the introduction of a group of electronic toys. One kit contains condensers, inductance coils, resistors, a radio tube, a microphone, etc., and a booklet which explains the different parts and gives instructions for using them. A sound effects kit has apparatus to produce 22 different sound effects. The New York Herald Tribune is cooperating with RCA to publish a facsimile newspaper at the World's Fair. Western Union has several automatic facsimile telegraph transmitters in operation at the San Francisco Fair. The first sound installation on an ocean going vessel to utilize hill-and-dale transcriptions was made by Western Electric on the new passenger liner SS Panama. A group of 500 passengers had its first experience with wireless communication at a television demonstration at the Frisco Fair.

**Selenium Rectifiers**. A discussion of the characteristics and uses in a bulletin by International Telephone Development Co., Inc., 67 Broad St., New York.

**Condensers**. For radio and automotive use described in catalog sheet by H. R. S. Products Co., 703 N. Cicero Ave., Chicago.


**Test Set**. For line and cable fault location in signal and communication circuits. Catalog E-53-44(b) Leeds and Northrup Co., 4067 Stenton Ave., Philadelphia.


**Electrical Connecting Devices**. Specifications and list prices given in set of bulletins by Howard B. Jones, 2300 Wabansia Ave., Chicago.


**Pilot Lamps**. Discussion of operation in series heater operated receivers in Bulletin 39-3. Also diagrams of tube bases. Tung-Sol Lamp Works, 95 Eighth Ave., Newark, N. J.

**Electrical Specialties**. Large variety described and also discussion of electrical equipment in new catalog of Ideal Commutator Dresser Co., Syracuse, Ill.

**Circuit Breaker**. In Catalog 6-c, insulation and bushing tester in Catalog 11-c, potential indicator in Catalog 11-b, and control relays in Catalog 12. Roller-Smith Co., 1766 West Market St., Bethlehem, Pa.

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**CONTROL BOARD OF INTERNATIONAL UNION OF RADIO FUSION**

The apparatus shown here monitors the short and long waves and is used to indicate the source of short wave interference at the International Union of Radio Fusion.

**Literature**

**Crystal Calibrator**. Inexpensive device for indicating 100 and 1000 kc points described in Bulletin E-7 by Billey Electric Co. Erie, Pa.

---

*July 1939 — Electronics*
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PILOT LIGHT ASSEMBLIES
A WIDE RANGE OF STYLES AND SIZES TO MEET EVERY REQUIREMENT

Regardless of the type of pilot light assembly you need, we can supply it better, quicker, and at lower cost. As the world's largest exclusive manufacturer, a large variety of standard units are available. If an assembly of special design is needed, our experienced engineers will be quick to develop the unit best suited to give dependable performance. Every detail of Drake Dial and Jewel Pilot Light Assemblies measures up fully to our rigid high standards of quality. Each unit is made with utmost precision, a modern high-speed equipment. Throughout inspection with electrical devices, assures perfect uniformity. Don't take chances. Specify DRAKE. You'll be highly pleased with the service and cooperation you'll get.

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Visit our exhibit at the World's Fair, in the Metals Building opposite the Trylon.

WILBUR B. DRIVER CO.
NEWARK, NEW JERSEY

STEATITE. Bulletin 39 gives more complete information than before. American Lava Corp., Chattanooga, Tenn.


Insulation. A large variety of electrical insulation materials described in Catalog 11, Insulation Manufacturers Corp., 565 West Washington Blvd., Chicago.


New Products --

Television Fuses

A SERIES of vacuum enclosed "Video" Littelfuse has been announced by Littelfuse, Inc., 4235 Lincoln Ave., Chicago. There are six sizes available between 1/100 and 1/16 ampere. These fuses protect high voltage equipment against damage and protect operators against lethal shocks. Because they operate in vacuum, the fuses will break as high as 20,000 volts.

Loudspeakers

THE WORLD'S LARGEST electrodynamic speaker, 27 inches in diameter, is announced by Cinaudagraph Corp., Stamford, Conn. This speaker has a linear response from 30 to 10,000 cps at a level of 85 watts. The voice coil is six inches in diameter and works in a gap whose flux density is 21,000 lines per sq in. The total weight of the speaker is 455 lbs. The list price is $500.

A DUAL LOUDSPEAKER with a low frequency unit and a high frequency unit in a single housing is announced by University Laboratories, 196 Chrystie St., New York. The frequency
New circuit
CONDENSER BRIDGE
covers all range requirements

Model 1640

$10.00

★ Red Hot Lifetime Guaranteed Meters.
★ 110 Volt 60 Cycle A.C. Operation.
★ Range 0.0005 to 250 mfd. Paper, Mica or Electrolytic Condensers.
★ Two-Color GOOD-BAD scale for Electrolytics from 2 to 250 mfd.
★ Voltmeter and Milliammeter in Circuit at Same Time for Leakage Test.
★ Capacity Measured at 60 Cycles.

By means of this new circuit perfected by Tripllett, paper or electrolytic condensers can be measured on direct reading scales, including accurate measurements on condensers with high leakage. Capacity is measured at 60 cycles. Leakage tests can be made up to 600 volts. The six direct reading scales have a total length of 36 inches. The red dot on the dial of the meter assures you a lifetime service and is a guarantee against defective material or workmanship in the measuring instrument.

Model 1640 in Metal Case with black suede finish, Dealer Net Price $90.00

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response is substantially flat from 60 to 10,000 cps without the use of filter networks. The power capacity is 25 watts continuously. A smaller unit is also available.

A line of permanent magnet and electro-dynamic speakers is announced by Lansing Mfg. Co., 6900 McKinley Ave., Los Angeles, Calif. These speakers are available in sizes from five inches to fifteen inches and are furnished complete with transformers.

Walnut Cabinet Amplifiers

Amplifiers are now being placed in attractive matched burl walnut cabinets by Thordarson Electric Mfg. Co., 500 West Huron St., Chicago. These cabinets feature a sloping front panel with "Edge Glow" illumination which makes for ease of operation and minimizes the need for remote control. These units are rated at 20, 30 and 45 watts.

Relay

A NEW GENERAL PURPOSE TRANSMITTER relay has been announced by Advance Electric Co., 1260 W. Second St., Los Angeles, Calif. This relay has been designed primarily as a substitute for larger and more expensive relays. The entire relay is above ground and may be mounted on any type of panel by means of the metal mounting bracket.

Communications Receiver

A REVISED MODEL of the Sky Buddy receiver is announced by Hallicrafters, Inc., 2611 Indiana Ave., Chicago. The new receiver, model S-19-R, has six tubes including the 6K8G. Continuous coverage from 545 kc to 44 Me is pro-
Current Flow Test Set

A CURRENT FLOW TEST SET No. 695 for

radio has been announced by Shall-

way Mfg. Co., Collingdale, Pa. The

purpose of this instrument is to pro-

vide a convenient and rapid means for
determining the flow of current through
d and other apparatus. The current
through the relay may be regu-
lized and measured so that the operator
non-operate currents may be deter-
mined.

Record Changer

A NEW RECORD CHANGER, model RC-
way, has been announced by Garrard Sales

1936 Broadway, New York. A non-

spindle eliminates the possibility of

clippage regardless of warpage.

is considerably smaller than the

vious model and is mounted so that

unit floats free of the cabinet. It

able with either a crystal pickup

high impedance magnetic pickup.

Two-Way Radio Telephone

A NEW TWO-WAY RADIO telephone has

announced by Western Electric

1936 Broadway, New York for use

ance and fire departments for

communication. The output has

creased to fifteen watts, three

much as in previous models, a

increase in demand on the

storage battery. A relay circuit

of the output of the receiver in

ence of any signal. Therefore,

as well as the receiver loudspeaker

periods of transmission.

Division Transmitter

ELECTRONICS — July 1939

Type 203 Synchronizing-Signal

or for studio control in tele-

transmitting stations has been

roduced by Allen B. DuMont Labs.,

Mahn Ave., Passaic, N. J. It has

igned to operate as the master

Greater Power, Speed and

Accuracy for Audio Work!

At New, Low Cost!

UNDUPLICATED flexibility, ease and speed of

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Frequency Oscillator, giving wide spread of low

frequencies to 100 cycles. A three-position range switch

enables (a) check at zero beat without disturbing

either dial setting, and (b) check at 400-cycle level

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Extremely accurate initial adjustment is facil-

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is so arranged that even more precise frequency

calibration is quickly and easily had by heterodyning

the oscillator output against the line frequency at

60 cycles or multiples thereof.

Many additional performance advantages are

fully described in a special brochure, mailed on

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MICRO SWITCH

Makes and breaks circuits where roller is needed be-

tween cam and switch lever. Especially suited for

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TYPE H and MICA CARD

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Available in a resistance range from 10 to 25,000 Ohms, size:

1/32 x 1/8 x 1/8; insulated eyelet mounting; 40 Watt; accuracy 2%

Resistance element sandwiched between two sheets of Mica. High

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The "most talked of" spectacles at the World's Fair are the breath-taking Water-Light and Sound display in the Lagoon of Nations and the awesome General Motors Futurama. For both of these spectacles, Cinaudagraph supplied the speakers. 27" dynamics for the nightly salt bath in the Lagoon; 6" dynamics for the "ride" on General Motors spectator belt.

Twin feats of magic in a magical world—it's all part of the job to Cinaudagraph engineers—the job of designing dependable speakers to meet every requirement. Take advantage of this skill and the experience behind it. On your next job, by all means specify Cinaudagraph speakers—they cost no more.

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ALL SHAPES — ALL SIZES
FOR ALL PURPOSES
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The new Leach Impulse Relays make possible many new developments such as new circuits, new lock-out schemes—alarm systems and safety devices. Operation is dependable, absolutely quiet, and fast... time required to shift from one position to the other is approximately 1/60 second.

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ELECTRONICS — July 1939

and an audio i f of 8.25 Mc. Both have a 200 microvolt sensitivity and a band width of four Mc. Magnetic deflection is used in both receivers.

Decimal Equivalent Chart

A DECALOMANIA measuring 8 by 11 inches which contains all the usual decimal equivalents from 1/64 to 63/64 inches is offered free by The Frederick Post Co., Box 803, Chicago. It is sized to fit the T-square so as to eliminate squinting at the distant figures of a wall chart.

Volt-ohmmeter

A VACUUM TUBE volt-ohmmeter, Model 660, was recently announced by Radio City Products Co., 88 Park Pl., New York. It will measure as low as 0.1 volts and as high as 2000 volts. The resistance range is from 0.1 ohms to 100 megohms. There are twelve ranges on this instrument.

New Tubes

AMONG THE new tubes announced by Hygrade Sylvania Corp., 500 Fifth Ave., New York are type 117Z6G, a full wave rectifier designed to operate with the heater directly across the a 117 volt power line, type 1232, which is similar to type 1231, except that additional shielding has been provided, and types 5AP1/1805-P1 and 5AP4/1805-P4, television picture tubes with green and white screens respectively which are electrostatically deflected.

SIX 1.4-VOLT tubes have been introduced by Arcturus Radio Tube Co., Newark, N. J. They are: 1A5G and

GT, power output pentode; 1A7G and GT, pentagrid converter; IC5G and GT, power output pentode; IH5G and GT, diode-triode; 1N5G and GT, r-f pentode; and 1Q6G and GT, beam power output tube. Also announced by Arcturus is a line of eight new dial lights.

A LOW COST type 866 mercury rectifier tube having a filament shield has

A new general purpose

RCA OSCILLOGRAPHER

for all laboratory and production uses!

5" CATHODE RAY TUBE! Ensures easy, accurate readings.

VERY LOW SWEEP RANGE! You can use this oscillograph at sweep frequencies as low as those used in engine pressure measurements.

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REQUIRED QUALITY! This is your assurance of satisfactory performance. Before being released for general use this instrument had to pass the quality tests required for our own laboratories.

SPLENDID VALUE! With all of the above features, this Oscillograph, Stock No. 160, is available at the price of only $130.00

SPECIFICATIONS

Deflection Sens. at Vert. Amp. input (gain max): 0.13 V. RMS per inch...Deflection Sens. Horiz. Amp.: 0.36 V. RMS per inch...Input at Vert. Amp. Input: 500,000 ohms, 15 mmf...Input Horiz. Amp.: 500,000 ohms, 15 mmf...Freq. characteristic Vert. Amp. (gain max): 3 cycles—50 KC essentially flat...Freq. characteristic Horiz. Amp.: 5 cycles—100 KC essentially flat...Max. signal input to Vert. Amp.: 500 volts RMS...Max. signal input to Horiz. Amp.: 500 volts RMS.

Over 135 million RCA radio tubes have been purchased by radio users...in tubes, as in parts and Test Equipment, it pays to go RCA All the Way.
been announced by Hytronic Laboratories, 76 Lafayette St., Salem, Mass. A pair of tubes will deliver up to 500 ma at d-c voltages up to 2385.

A complete line of television picture tubes, both electrostatically and electromagnetically deflected, has been announced by Cath-Ray Electronics Corp., 115 Edison Pl., Newark, N. J.

A seven-inch and a five-inch cathode ray tube are announced by Northern Manufacturing Co., 36 Spring St., Newark, N. J.

Several new tubes are announced by RCA Manufacturing Co., Harrison, N. J. Types 2050 and 2051 are hot-cathode gas tetrodes, type 1024 is a transmitting beam power amplifier.

Types 924 and 927 are gas phototubes with caesium-surfaced cathodes, type 925 is a vacuum phototube with a caesium-surfaced cathode, type 926 is a vacuum phototube with a rubidium-surfaced cathode, and type 5AP1/1805-P4 is a 5-inch electrostatic deflection kinescope with white phosphor.

Rotary Converters

A new line of rotary converters, the Pioneer "K" Series, is announced by Pioneer Gen-E-Motor Corp., 466 West Superior St., Chicago. The following units are available: Type AK, 100 to 200 watts; Type BK, 300 to 500 watts and Type CK, 750 to 1000 watts as well as units of greater capacity. They are available with filters for radio operation. Pioneer also announces new lines of motor generator sets and centrifugal pumps.

Contour Shaping Machines

Do-all contour shaping machines are available from Continental Machines, Inc., Minneapolis, Minn. Contour sawing, filing and polishing are all done on one machine which also replaces such operations as nibbling or torch cutting. Large savings are possible in cutting tool steel, special shapes, making jigs and fixtures, templates, automatic true circles, cutting non-ferrous metals and plastics, and making experimental parts and models. There are several sizes available.

Television Antennas

A new indoor television antenna has been announced by Consolidated Wire & Associated Corps., 520 S. Peoria St., Chicago. There are two telescopic brass rods which allow for adjustment to the exact frequency to be received. A low loss transmission line is used, 75 feet of which is provided with the unit.

A television antenna with universal joint mounting which permits adjustments in all directions is announced by Technical Appliance Corp., 17 E. 16th St., New York. It is constructed of heavy dural rods held together with a center insulator. Extension rods screw into the center rods for attaining the correct length of the dipole. A reflector is available for this antenna.

Coil Form

An improved coil form tubing is offered by Spaulding Fibre Co., 484 Broome St., New York. It is mechanically and electrically strong, tough and rugged, impervious to changing atmospheric conditions, immune to electrolysis, and easily punched, machined and threaded. Moisture tests show less than 1.5 per cent absorption on a 1/16 inch wall in 24 hours immersion.

Rheotrol

The Rheotrol, a stepless 0 to 100 per cent manual control for electrically operated furnaces, ovens, etc., has been announced by Wheelco Instruments Co., 1929-1933 So. Halsted St., Chicago. It consists of rotating cams operating switches to make and break the current. For example; if it is set...

Electronic Device Paces Runners

A group of track men testing out an electronic device invented by George Dadakis of the Massachusetts Institute of Technology. The track is divided into four points, at each of which a post is erected. As the runner passes the post, a bell rings. It is expected that by this method, the runner may time himself better on each lap.

Tungsten and Molybdenum - Kilgrid Lead-in Wires

Leading tube manufacturers are well acquainted with the life-long dependability and production of Kilgrid lead-in wires. These products, both Kilgrid and Molybdenum, are held in wires. Don’t accept inferior substances. Depend on Callite quality products for maximum production efficiency. Call on Callite engineers for detailed information on fluorescent materials, lead-in wires and contact points.

Callite Products Division

Eisler Electric Corp. • 544 39th St. • Union City, N. J.
Aircraft Antenna System

A TRAILING WIRE aircraft antenna system, type AV-A-41, has been announced by the Aviation Section, RCA Manufacturing Co., Camden, N. J. When installed in the recommended manner above the ship, this antenna permits short distance communication when it is reeled in. The pull exerted by the drag unit is substantially the same at all speeds so that there is little difficulty in reeling in the wire at high speeds.

Silicon Brazing Alloys

LOW TEMPERATURE silicon brazing alloys are available from Handy & Harman, 82 Fulton St., New York. These alloys flow freely at 1175 degrees F and have the following advantages: Joints are made which are ductile and have high tensile strength, electrical conductivity is as high or higher than copper, the joints cannot oxidize and little finishing work is required.

Sound System

A NEW SOUND system is announced by Electrical Research Products, Inc., 195 Broadway, New York. The new system has been designed to anticipate future advances in recording such as the high volume motion picture prints scheduled to appear shortly. Acoustic compensators enable the system to be tailored to fit to the particular auditorium in which it is installed. Flutter in the associated projector has been greatly reduced by the development of a new scanner fluid.

Voltmeter

A NEW ZERO current voltmeter, model 210X, has been announced by Hickok Electrical Instrument Co., DuPont Ave., Cleveland, Ohio. This instrument has ranges for measuring up to 10,000 volts. It will also measure currents up to 25 amperes, resistances up to 50 megohms, capacitances to 200 microfarads. A decibel range is included.

FOR ACCURATE, DEPENDABLE
high frequency
CRYSTAL CONTROL

The type MO2 and MO3 Billey High Frequency Quartz Crystal Units are designed to provide accurate, dependable frequency control under the adverse operating conditions encountered with mobile and portable transmitters. Catalog G10 contains complete information. Write for your copy.

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REMLER ATTENUATORS

Standard impedances of 50, 200, 250 and 500 ohms. Special values to order.

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Why should you pay $85 to $100 for a vacuum tube when an Eimac 250T will do the job better at much less cost?

EIMAC 250T

- It may surprise you to know that an Eimac 250T tube selling for $74.50 will outperform many well known vacuum tubes that sell for $85 and more.

It's no longer a surprise to the hundreds of commercial and police radio station owners who have replaced these expensive tubes with the more efficient Eimac 250T. A one thousand hour test of Eimac tubes will prove conclusively that their superior quality and ability to outperform most other tubes of like ratings will save you money in the long run.

Why don't you get acquainted with Eimac tubes now? Save dollars and get better all around performance. Your correspondence will be sincerely appreciated.

EITEL-McCULLOUGH, INC.
788 San Mateo Street, San Bruno, Calif.
CuO Rectifiers

(Continued from page 18)

Halves of the carrier cycle, $R_n$ is an average resistance taken over a half-cycle in the conducting direction and $R_n$ is the same in the non-conducting direction. This representation demands that the carrier act simply as a reversing switch, commutating instantaneously at its own frequency. Mathematically a reversing switch of this type can be represented by a square-top wave whose amplitude alternates between $+1$ and $-1$. This can be expressed by a Fourier series expansion of the form,

$$f(t) = \frac{4}{\pi} \cos \omega_0 t - \frac{1}{3} \cos 3\omega_0 t + \frac{1}{5} \cos 5\omega_0 t - \ldots$$

wherein $\omega_0$ is equal to $2\pi$ times the frequency of the carrier. With this representation, the output current $I_o$ will be proportional to the product of $I$, times $f(t)$; the factor of proportionality being determined by the losses encountered in the resistors of the modulator network. If we represent this factor by $e^{-t}$ we have the equation,

$$I_o = I_i e^{-P/\omega_0}.$$  

Because the circuit configuration is identical to that of a lattice structure, we can express $P$ as being the propagation constant of a lattice network. This is expressed by

$$P = -\log_{10} \left( \frac{R_n}{R_i} \right).$$

(3)

It can be shown that for maximum transfer of power,

$$z_i = 2\pi f \approx R = \sqrt{R_i \cdot R_n}.$$ 

(4)

If, now we let the impressed voltage have a frequency $f_i$ and if we assume for the moment that the resulting current $I$, is of this frequency alone, then expansion of Equation (2) will show that $I$, is made up of frequencies $(n\omega_i \pm f)$, where $a_n$ may take on the odd integral values $1, 3, 5, 7, \ldots$. However, it is a property of non-linear circuits that if a voltage of a certain frequency is impressed across the input terminals of such a network, the resulting current, in this case $I$, will be composed of a summation of com-
ponents whose frequencies are either multiples of the impressed frequency or sums and differences between the impressed and other frequencies in the circuit. For this reason, \( I \) cannot be considered as composed of a single component of frequency \( f \). Due to the bidirectional property of the lattice structure, we can express these new current components, \( I' \), by

\[
I' = I_0 e^{j\phi(t)}.
\]  

(5)

Expansion of equation (5), assuming that \( I_0 \) is composed of the frequencies found from Equation (2) shows that \( I' \) will be composed of frequencies \( (a_0 f_0 \pm f_0) \), where \( a_0 \) may take on the even integral values 0, 2, 4, 6, ... The true input current \( I \) is the sum of a large number of currents of different frequencies and its value can only be arrived at by a series of successive approximations.

In actual practice the carrier voltage \( (E_{in}) \) is adjusted to be about 0.5 volts rms across each disc in the conducting direction. Caruthers has shown that components other than the major sum and difference frequencies \( (f \pm f_0) \) decrease much more rapidly than \( f_0 \) as the amplitude of the signal is reduced. For ordinary speech frequencies satisfactory terminating resistors range in value between 500 and 1,000 ohms, while the internal impedance of the carrier generator should be as low as possible, especially at signal frequencies. For frequencies of three or four megacycles, terminating resistors of 50 ohms or less must be used because of the increased importance of the shunt capacitances. The loss of energy between a single sideband and the input signal ranges between three and six db depending on the frequencies and the terminating impedances.

The bridge modulator serves well as the mixing unit in a beat frequency oscillator. Here, for example, two frequencies of about 150,000 cps are combined to produce a beat frequency varying between 20 and 50,000 cycles. It is desired here that the output be exceedingly free from harmonic distortion and have a constant amplitude throughout the frequency range. If the variable oscillator is connected as \( E_{in} \) then the beat frequency will be independent of any variations in the amplitude of \( E_{in} \) if \( E_{in} \) is large in comparison to the amplitude of the signal from the other oscillator. The

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**ELECTRONICS — July 1939**
output can be made quite free from harmonic distortion by reducing the terminal impedances to a few hundred ohms and by reducing the amplitude of $E_I$ to a small value. However, because of the low output under such conditions, considerable amplification is needed, following the mixer. This brings on additional complications in compact a-c operated equipment due to hum and distortion introduced by the amplifier.

We have found another region of operation for the mixer which also meets the distortion and amplitude requirements mentioned above and in addition gives a higher difference tone output. The circuit is shown in Fig. 13. The novel features are the high terminating impedance and the fact that the magnitudes of the two radio frequency voltages must be adjusted to reasonably specific values. This can be done empirically by employing a wave analyzer to determine at what voltages the harmonic distortion becomes a minimum. These voltages depend somewhat on the units employed, the terminating impedances, and the frequency of the oscillators. When properly adjusted, harmonic distortions as low as 0.05 per cent can be obtained with a difference tone amplification.

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**Positions Wanted**

**CERTIFIED RADIO TECHNICIAN** with experience in television design and construction, public address systems, receivers and transmitters. 5½ years instructor in New York State high schools in physics, mathematics, and drafting. B.S. degree. Age 35. Married. Laboratory research and testing experience in wood finishing products. Ceramical and textile work. Desires position in research or development of photo cells, amplifiers, instruments or parts. PW-226, Electronics, 320 W. 42nd St., New York, N. Y.

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**ANYTHING** within reason that is wanted in the field served by Electronics and is quickly bringing it to the attention of thousands of men whose interest is aroused because this is the business paper they read.

July 1939—ELECTRONICS
amplitude of 0.1 volt. Another significant feature of this circuit is that both oscillators and the output have a common ground and only one simple intermediate frequency transformer is required. The circuit constants for one of the experimental models built in this laboratory are shown on the schematic, along with the approximate values of the oscillator voltages. The output of this mixer has remained constant and free from distortion for a period exceeding a year under conditions of several hours use daily.

Gas Analysis. In a process for analyzing gas in which a sample of gas is burned with air in contact with a heated catalyst wire mounted in a Wheatstone bridge circuit and the temperature rise of the catalytic wire resulting from the combustion is measured by a galvanometer, a full-wave rectifier supplies alternating voltages to the bridge. Benjamin Miller, Power Patents Co., No. 2,152,439.


Gas Detection Apparatus. Apparatus for detecting the presence of dangerous gases by a light reflecting strip impregnated with a solution effective on reaction with such gases to substantially reduce the light reflecting property of the strip. C. W. Johnson, South Weymouth, Mass. No. 2,152,568.


Engine Indicator. System for indicating synchronism of a pair of internal combustion engines, utilizing vacuum tubes corresponding to each of two magneto's. C. I. McNeil, Eclipse Aviation Corp. No. 2,152,264.

Inverter. Device for changing a direct current voltage of varying magnitude and reversible polarity into an alternating current voltage of proportional amplitude and reversible phase. George Agins, the Arma Engineering Co., No. 2,149,718.


Door Control System. Tube controlled door operating system involving devices with burned in air with a galvanometer, a full-wave rectifier supplies alternating voltages to the bridge. Benjamin Miller, Power Patents Co., No. 2,152,439.

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Increasingly... the trend is toward MICRODYNE... and with warm weather this tendency becomes only more pronounced.

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INDEX TO ADVERTISERS

INDEX TO ADVERTISERS

<table>
<thead>
<tr>
<th>Advertiser</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeolus Collods Corp.</td>
<td>55</td>
</tr>
<tr>
<td>Atom Co., Inc.</td>
<td>66</td>
</tr>
<tr>
<td>Allen Products Co.</td>
<td>63</td>
</tr>
<tr>
<td>Alimed Control Co.</td>
<td>72</td>
</tr>
<tr>
<td>American Amateur Electric Sales Co.</td>
<td>57</td>
</tr>
<tr>
<td>American Lawn Corp.</td>
<td>5</td>
</tr>
<tr>
<td>American Transformers Co.</td>
<td>7</td>
</tr>
<tr>
<td>American Microphone Laboratory, Inc.</td>
<td>69</td>
</tr>
<tr>
<td>Audax Co.</td>
<td>73</td>
</tr>
<tr>
<td>Bakelite Corp.</td>
<td>49</td>
</tr>
<tr>
<td>Bendix Engine Co.</td>
<td>68</td>
</tr>
<tr>
<td>Biddle Co., James &amp; Co.</td>
<td>53</td>
</tr>
<tr>
<td>Hilley Electric Co.</td>
<td>67</td>
</tr>
<tr>
<td>Callinet Products Div. Eberly Electric Corp.</td>
<td>66</td>
</tr>
<tr>
<td>Cannon Elec. Development Co.</td>
<td>40</td>
</tr>
<tr>
<td>Centralab Div. Globe Union Co.</td>
<td>64</td>
</tr>
<tr>
<td>Conmandograph Corp.</td>
<td>66</td>
</tr>
<tr>
<td>Crouch Manufacturing Co.</td>
<td>64</td>
</tr>
<tr>
<td>Clothene Corp.</td>
<td>63</td>
</tr>
<tr>
<td>Cross &amp; Co.</td>
<td>68</td>
</tr>
<tr>
<td>Daven Co.</td>
<td>48</td>
</tr>
<tr>
<td>Drake Mfg. Co.</td>
<td>61</td>
</tr>
<tr>
<td>Driver Co., William B.</td>
<td>61</td>
</tr>
<tr>
<td>Du Mont Laboratories, Inc., Allen H.</td>
<td>72</td>
</tr>
<tr>
<td>Eaker Engineering Co.</td>
<td>68</td>
</tr>
<tr>
<td>Eitel-McCullough, Inc.</td>
<td>67</td>
</tr>
<tr>
<td>Electrical Research Products, Inc. Engineering Co. of Newark, N. J., Inc.</td>
<td>68</td>
</tr>
<tr>
<td>Elite Research Corp.</td>
<td>41</td>
</tr>
<tr>
<td>Forncina Insulation Co.</td>
<td>53</td>
</tr>
<tr>
<td>Gerrard Sales Corp.</td>
<td>70</td>
</tr>
<tr>
<td>General Electric Co. Plastics Dept.</td>
<td>58</td>
</tr>
<tr>
<td>General Laminated Products, Inc.</td>
<td>50</td>
</tr>
<tr>
<td>General Radio Corp.</td>
<td>5</td>
</tr>
<tr>
<td>Goat Radio Tube Corp.</td>
<td>59</td>
</tr>
<tr>
<td>Heinrich &amp; Kaufman Ltd.</td>
<td>71</td>
</tr>
<tr>
<td>Hunter Pressed Steel Corp.</td>
<td>69</td>
</tr>
<tr>
<td>International Nickel Co.</td>
<td>47</td>
</tr>
<tr>
<td>International Resistance Co.</td>
<td>39</td>
</tr>
<tr>
<td>Isolantite, Inc.</td>
<td>39</td>
</tr>
<tr>
<td>Jones, Howard B.</td>
<td>55</td>
</tr>
<tr>
<td>Lamplin Laboratories</td>
<td>68</td>
</tr>
<tr>
<td>Lamp Insulator Co.</td>
<td>3</td>
</tr>
<tr>
<td>Latch Relay Co.</td>
<td>45</td>
</tr>
<tr>
<td>Leitz Electric Mfg. Co. Third Cover</td>
<td>71</td>
</tr>
<tr>
<td>Leuppi &amp; Son, Inc. John E.</td>
<td>58</td>
</tr>
<tr>
<td>Latelmit Co.</td>
<td>71</td>
</tr>
<tr>
<td>Mallory &amp; Sons, P. R.</td>
<td>8</td>
</tr>
<tr>
<td>Met-Gray Mill Book Co.</td>
<td>62</td>
</tr>
<tr>
<td>Miles Reproduco Co.</td>
<td>74</td>
</tr>
<tr>
<td>McRae Switch Corp.</td>
<td>63</td>
</tr>
<tr>
<td>Ohsune Manufacturing Co.</td>
<td>58</td>
</tr>
<tr>
<td>Pioneer Gas Motor Corp.</td>
<td>54</td>
</tr>
<tr>
<td>Precision Paper Tube Co.</td>
<td>57</td>
</tr>
<tr>
<td>Precision Resistor Co.</td>
<td>63</td>
</tr>
<tr>
<td>Presto Recording Corp.</td>
<td>44</td>
</tr>
<tr>
<td>Radio Corp. of America</td>
<td>43</td>
</tr>
<tr>
<td>Raytheon Mfg. Co.</td>
<td>57</td>
</tr>
<tr>
<td>RCA Communications, Inc.</td>
<td>69</td>
</tr>
<tr>
<td>RCA Manufacturing Co. 65, Fourth Cover Neon Co., Ltd.</td>
<td>6</td>
</tr>
<tr>
<td>Richardson Co.</td>
<td>56</td>
</tr>
<tr>
<td>Sigma Instruments, Inc.</td>
<td>70</td>
</tr>
<tr>
<td>Superior Tube Co.</td>
<td>4</td>
</tr>
<tr>
<td>Thomas &amp; Skinner Steel Pds. Co.</td>
<td>64</td>
</tr>
<tr>
<td>Triplett Electrical Instrument Co.</td>
<td>62</td>
</tr>
<tr>
<td>Tubular Wire &amp; Stud Co.</td>
<td>59</td>
</tr>
<tr>
<td>Vacation, Inc.</td>
<td>68</td>
</tr>
<tr>
<td>Western Electric Co.</td>
<td>6</td>
</tr>
<tr>
<td>White Dental Mfg. Co., S. S.</td>
<td>56</td>
</tr>
</tbody>
</table>

Professional Services

SEARCHLIGHT SECTION

Classified Advertising

EMPLOYMENT

ELECTOR Electric Corp. | 70
Kable Engineering Corp. | 70
Laws, Garrett W. | 70

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Without Conductor Breakage!

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FOR CRYSTAL, VELOCITY AND DYNAMIC MICROPHONES
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LENZ ELECTRIC MANUFACTURING CO.
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"IN BUSINESS SINCE 1904"

ELECTRONICS — July 1939
One Tube Does the Work of Two

**Stability Plus Dependability on Direct Operation from a Phototube**

**With the New RCA Hot-Cathode Gas Tetrodes**

Having extreme sensitivity and wide range of grid-voltage characteristics, the new RCA 2050 and 2051 tetrodes are ideally adapted for use in control devices requiring particularly high performance in grid-controlled rectifiers and relay applications. Important savings in grid-controlled rectifiers and relay applications are also possible with the tubes because of the long-tailed type of construction and low plate current of the indirectly heated, hot-cathode type. A continuous tetrode is suitable for the new RCA 2050 and 2051 tetrodes as well as for conventional circuits.

**Characteristics**

- **Grid Resistance**: Approximately 325 ohms
- **Grid Current**: Less than 0.5 mA
- **Plate Current**: Less than 0.5 mA
- **Plate Voltage**: 500 V
- **Grid Efficiency**: Approximately 75% of the amperes of plate current

The grid efficiency is approximately 75% of the amperes of plate current, and the plate current is extremely low, permitting high grid sensitivity to be achieved. The resulting high grid sensitivity permits the tube to be used as a high-frequency detector in radio circuits.

**Conclusion**

The new RCA 2050 and 2051 tetrodes offer a unique combination of sensitivity and stability, making them ideal for a wide range of applications in direct operation from a phototube.