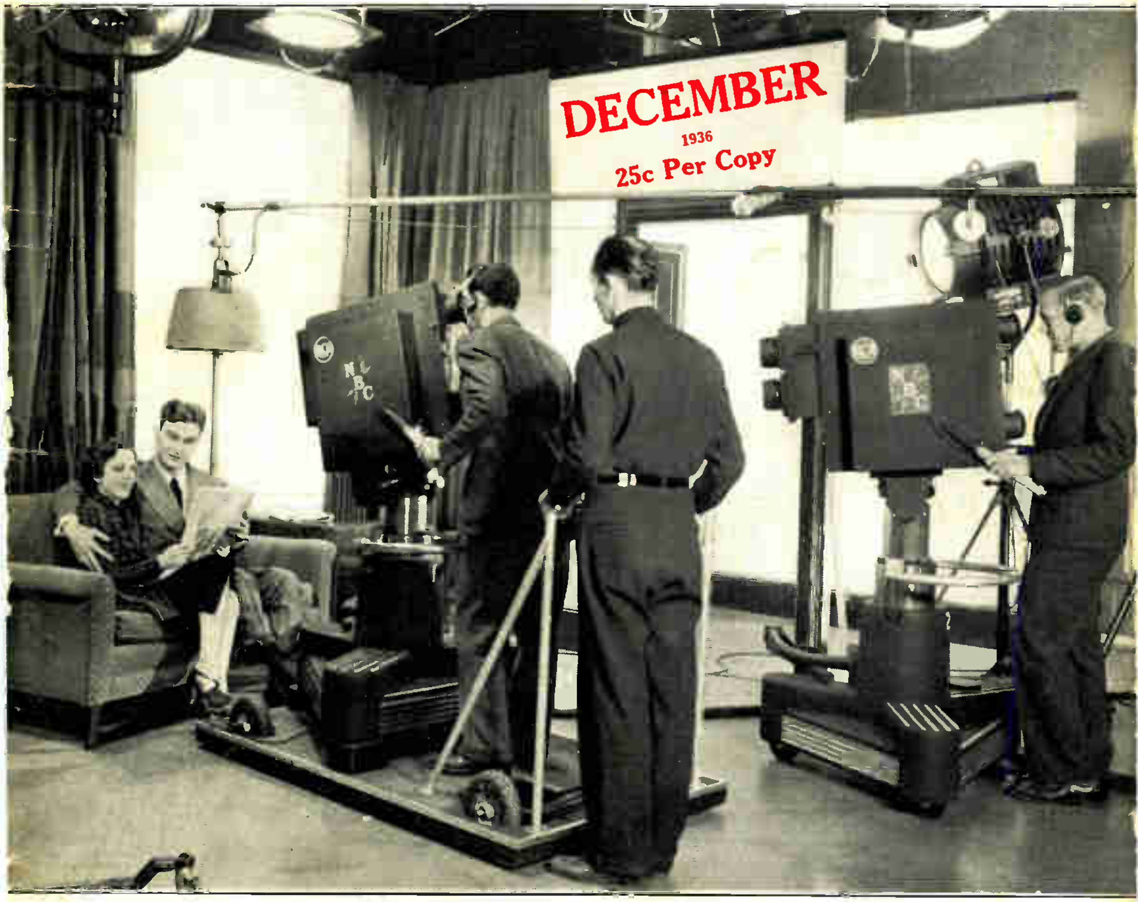
PROPER SERVICE PRICES

RADIO WORLD

REG. U. S. PAT. OFF.

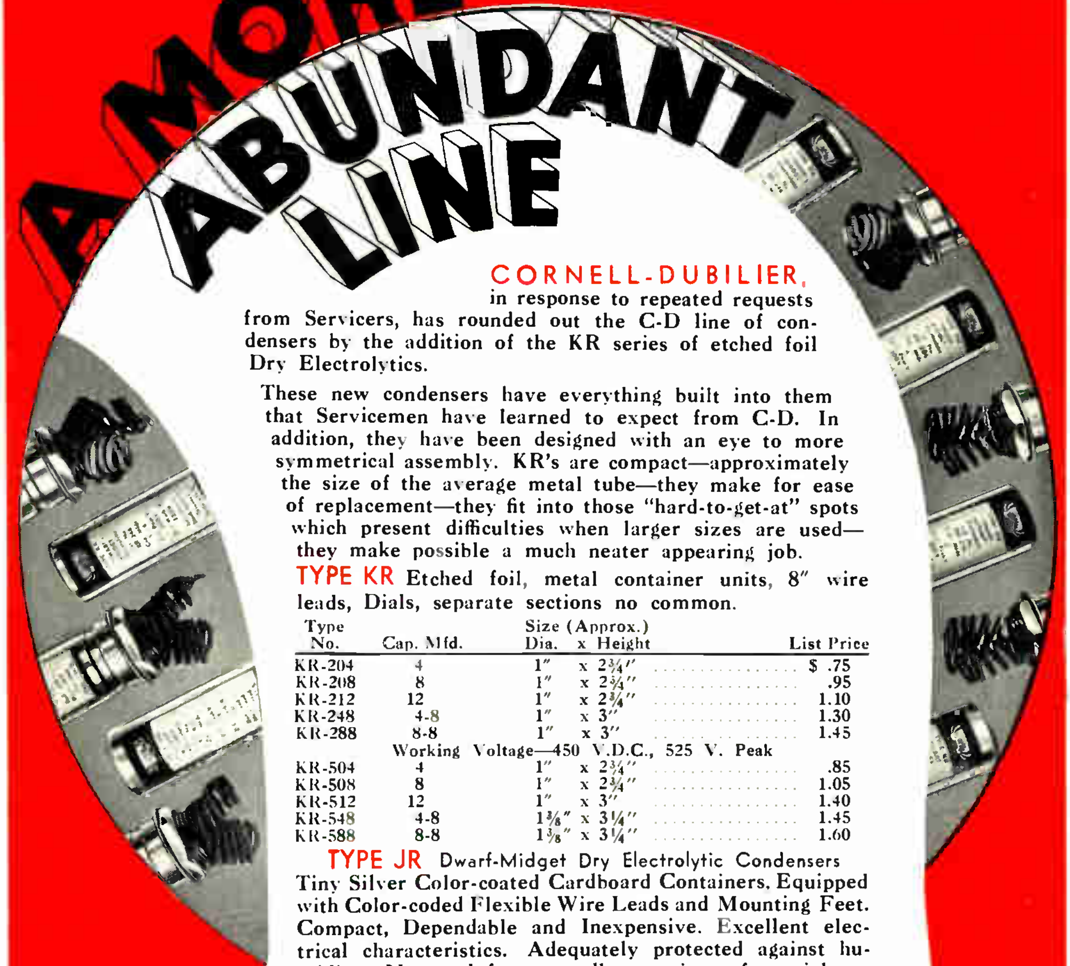
TELEVISION ADVANCE DEMONSTRATED



DECEMBER
1936
25c Per Copy

STUDIO WHERE ADVANCED TECHNIQUE OF RCA CATHODE-RAY TELEVISION WAS DEMONSTRATED RECENTLY. SEE PAGE 34.

A MORE ABUNDANT LINE



CORNELL-DUBILIER, in response to repeated requests from Servicers, has rounded out the C-D line of condensers by the addition of the KR series of etched foil Dry Electrolytics.

These new condensers have everything built into them that Servicemen have learned to expect from C-D. In addition, they have been designed with an eye to more symmetrical assembly. KR's are compact—approximately the size of the average metal tube—they make for ease of replacement—they fit into those "hard-to-get-at" spots which present difficulties when larger sizes are used—they make possible a much neater appearing job.

TYPE KR Etched foil, metal container units, 8" wire leads, Dials, separate sections no common.

Type No.	Cap. Mfd.	Size (Approx.) Dia. x Height	List Price
KR-204	4	1" x 2¾"	$ .75
KR-208	8	1" x 2¾"	.95
KR-212	12	1" x 2¾"	1.10
KR-248	4-8	1" x 3"	1.30
KR-288	8-8	1" x 3"	1.45
Working Voltage—450 V.D.C., 525 V. Peak			
KR-504	4	1" x 2¾"	.85
KR-508	8	1" x 2¾"	1.05
KR-512	12	1" x 3"	1.40
KR-548	4-8	1⅜" x 3¼"	1.45
KR-588	8-8	1⅜" x 3¼"	1.60

TYPE JR Dwarf-Midget Dry Electrolytic Condensers

Tiny Silver Color-coated Cardboard Containers, Equipped with Color-coded Flexible Wire Leads and Mounting Feet. Compact, Dependable and Inexpensive. Excellent electrical characteristics. Adequately protected against humidity. No need for an endless variety of special expensive exact duplicate replacements.

200 V.D.C. Working Voltage—250 V.D.C. Peak Voltage.
SINGLE Section Units; Red Lead Positives; Black Negative.

Cat. No.	Cap. Mfd.	Size	Price List
JR-204	4	2 7/16" x ¾" x ½"	$0.65
JR-208	8	2 7/16" x 1" x 9/16"	.80
JR-210	10	2 7/16" x 1" x 9/16"	.90

450 V.D.C. Working Voltage. 525 V.D.C. Peak Voltage.

Cat. No.	Cap. Mfd.	Size	Price List
JR-502	2	2 7/16" x ¾" x ½"	$0.65
JR-504	4	2 7/16" x 1" x 9/16"	.75
JR-508	8	2 7/16" x 1⅛" x 11/16"	.95

Complete listing and data available—Write for catalog No. 134A today!

PAPER

MICA

DYKANOL

WET & DRY

ELECTROLYTIC

CORNELL-DUBILIER CORPORATION
1024 Hamilton Boulevard
So. Plainfield, N. J.

CORNELL CD DUBILIER

RADIO WORLD, December, 1936. Published monthly. Vol. XXIX. No. 9. Whole No. 699. Address, 145 West 45th Street, New York, N. Y. Subscription price, $2.50 per annum (foreign, $3.00). Single copy, 25c. Published by Hennessy Radio Publications Corporation. Entered as second class matter March, 1922, at the Post Office at New York, N. Y., under Act of March 3rd, 1879.

I WILL TRAIN YOU AT HOME *in Spare Time* FOR A GOOD RADIO JOB


J. E. SMITH, President
National Radio Institute

Many Radio Experts Make $30, $50, $75 a Week

Do you want to make more money? Broadcasting stations employ engineers, operators, station managers and pay up to $5,000 a year. Spare time Radio set servicing pays as much as $200 to $500 a year—full time servicing jobs pay as much as $30, $50, $75 a week. Many Radio Experts own their own full time or part time Radio businesses. Radio manufacturers and jobbers employ testers, inspectors, foremen, engineers, servicemen, paying up to $6,000 a year. Radio operators on ships get good pay and see the world besides. Automobile, police, aviation, commercial Radio, and loud speaker systems offer good opportunities now and for the future. Television promises many good jobs soon. Men I trained at home are holding good jobs in all these branches of Radio.

Many Make $5, $10, $15 a Week Extra in Their Spare Time While Learning

Practically every neighborhood needs a good spare time serviceman. The day you enroll I start sending you Extra Money Job Sheets. They show you how to do Radio repair jobs that you can cash in on quickly. Throughout your training I send you plans and ideas that have made good spare time money for hundreds of fellows. I send you special equipment which gives you practical Radio experience—shows you how to conduct experiments and build circuits which illustrate important principles used in modern Radio sets. My Free Book tells all about this.

Find Out What Radio Offers You

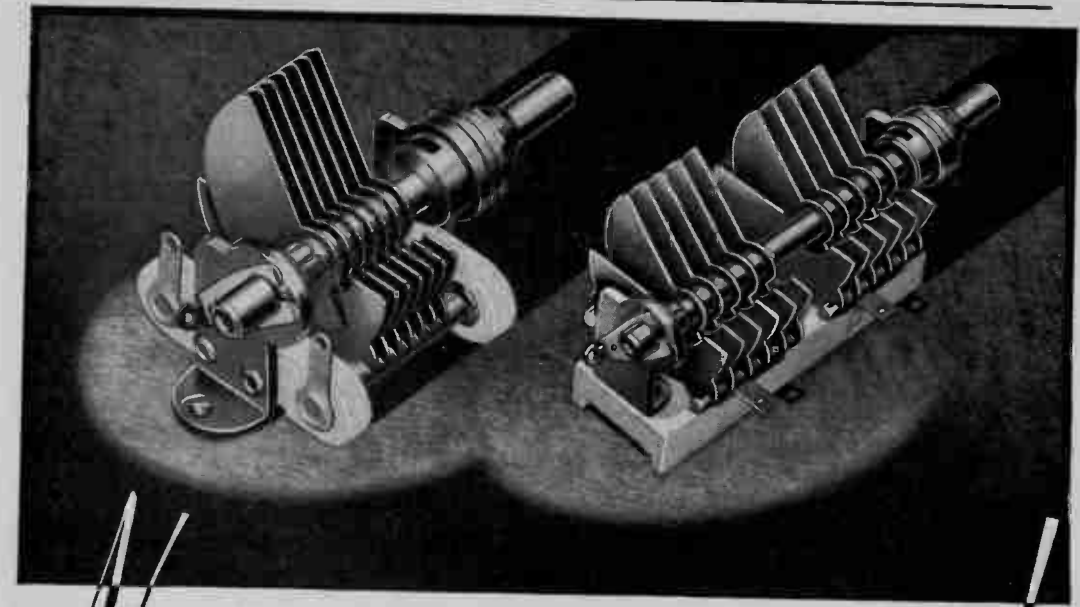
Mail the coupon now for "Rich Rewards in Radio." It's free to any fellow over 16 years old. It describes Radio's spare time and full time opportunities, also those coming in Television; tells about my training in Radio and Television; shows you actual letters from men I have trained, telling what they are doing and earning; tells about my Money Back Agreement. MAIL THE COUPON in an envelope, or paste it on a penny postcard—NOW!

J. E. SMITH, President
National Radio Institute, Dept. 6NM4
Washington, D. C.

J. E. SMITH, President
National Radio Institute, Dept. 6NM4
Washington, D. C.

Dear Mr. Smith: Without obligating me, send "Rich Rewards in Radio," which points out the spare time and full time opportunities in Radio and explains your 50-50 method of training men at home in spare time to become Radio Experts. (Please Write Plainly.)

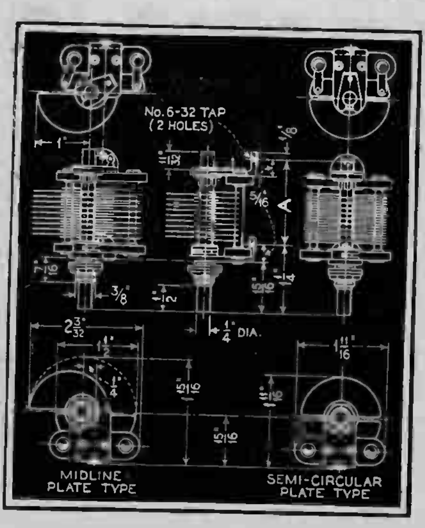
NAME...AGE............
ADDRESS..
CITY...STATE..............



New MIDGET CONDENSERS!

HAMMARLUND proudly presents a new complete series of "MC" variable condensers with exclusive features that set a new and dominant standard for condenser design.

Single and split stator types use cadmium plated soldered brass plates and Isolantite insulation to assure lowest losses and highest efficiency under all conditions of temperature and humidity. Strictly noise-free operation, even at the ultra-high frequencies, is insured with a new, split type rear bearing, plus a new, noiseless silver-plated Beryllium wiping contact.



Available in 27 different sizes—single and split-stator models—20 to 325 mmf.—midline or semi-circular plates—single hole panel and base mounting. Illustrated above are the "MC" single with midline plates, and the "MCD-MX" split-stator type with double spaced midline plates.

A special leaflet completely describing these new "MC" condensers has just been prepared and will be sent to you free of charge. Just mail the coupon below.

HAMMARLUND MANUFACTURING CO., Inc.
424-438 W. 33rd St., New York City RW-12
☐ Check here for new "MC" leaflet.
☐ Check here for new Hammarlund "37" Catalog.
Name ....
Address ....
....

HAMMARLUND'S 25TH YEAR

PRECISION PRODUCTS FOR BETTER RADIO


AUTO-RADIO
INSTALLATION AND SERVICING
Hygrade Sylvania Corporation
SYLVANIA SET-TESTED RADIO TUBES

RADIO WORLD

Fifteenth Year

ROLAND BURKE HENNESSY *Editor*
HERMAN BERNARD *Managing Editor*
HERBERT E. HAYDEN *Advertising Manager*

Table of Contents for DECEMBER, 1936

NEXT MONTH

RADIO WORLD for January will contain some unusually interesting articles. One is about a rig using the new little 913 cathode-ray oscillograph tube. Since this tube will probably list at $5.60, now you can go places at small cost. Yet the service, as to versatility, is on a par with that of other oscilloscopes. Surely this fascinates you. It does us.

Other articles concern a volume-expander, balanced detector, high-fidelity superheterodyne; a short-wave converter so simple it works well (yes, this one does!); and a very fine service instrument based on a positive mu signal generator.

Vol. XXIX, December, 1936. No. 9. Whole No. 699. RADIO WORLD, published monthly by Hennessy Radio Publications Corporation, 145 West 45th Street, New York, N. Y. Editorial and executive offices, 145 West 45th Street, New York, N. Y. Executives of RADIO WORLD: Roland Burke Hennessy, editor and business manager; Herman Bernard, managing editor; Herbert E. Hayden, advertising manager. Officers of corporation: Roland Burke Hennessy, president-treasurer; Roland Burke Hennessy, Jr., vice-president; Herman Bernard, secretary. Entered as second-class matter March, 1922, at the Post Office at New York, N. Y., under Act of March 3d, 1879.

SUBSCRIPTION RATE

Price 25 cents per copy. Subscription $2.50 per year (12 issues); $1.25 per six months (6 issues); postpaid in United States and Possessions; $3.00 per year, $1.50 per six months, postpaid in all other countries. Remittance for foreign subscription should be by International money-order (postal or express) or draft against or discountable at New York bank.

RADIO WORLD is distributed by the American News Company and its Branches

Rapid Inductance Rig

R.F. Coils Measured, Using Ray Tube

By Kenneth H. Tiffany

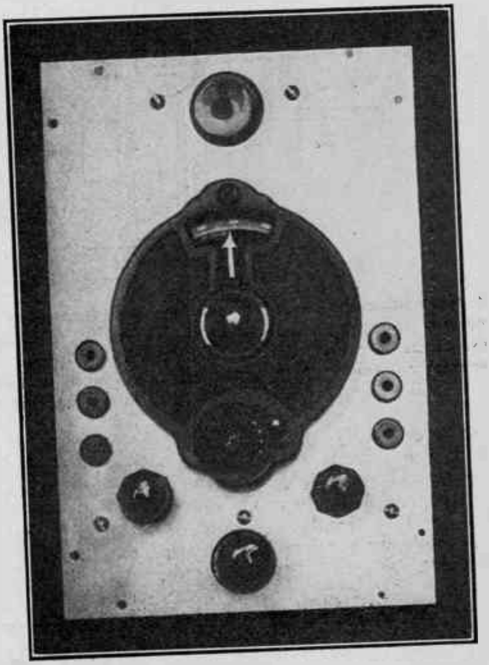
THE measurement of radio-frequency inductance, particularly the pure inductance, as well as the matching of coils where close tracking is required, presented something of a problem until a method was developed based only on capacity difference as interpreted in difference of wavelengths squared. This method was expounded by Herman Bernard in the September, 1936, issue, and the present rig is one application.

In general, the unknown inductance depends on the difference between two readings, and this difference is occasioned by the comparison of wavelengths squared, when a critical capacity of 281.7 is in circuit and when it is out of circuit. Whatever extra capacity is in circuit, so long as it stays there, does not matter, and the answer is in pure inductance, not in apparent inductance. The pure inductance is the inductance itself. The apparent inductance is what the inductance seems to be when the other factors, particularly the distributed capacity, are considered as if their effects were due to inductance. Of course a measurement of apparent inductance may be just a glorified guess as to what the real inductance is.

SPECIAL TYPE GENERATOR

As the principle was explained fully in the September issue there is no need to go into it here, except to explain that now we are using low-frequency generations, and comparing them with the unknown inductance, and harmonics of the low-frequency generator are acceptable. Assuming that the coil in the generator circuit (left in diagram) is larger in inductance than the largest inductance desired to be measured, a small condenser may be used for covering a small range of frequencies. These may be plotted as such, converted to wavelengths, then squared, so that the differences as read from a curve will yield the inductance, in centimeters, however. For the usual microhenries divide by 1,000. Or if a wavelength-squared scale is to be protracted and affixed to a dial, the division of the values of squares by 1,000 may be used right on the scale, so that the difference automatically will be divided by 1,000, and direct reading in microhenries will be the result.

The generator is of the negative resistance type. But it is not a dynatron and therefore does not depend on secondary emission. No particular name has been applied to it, as it is the latest type oscillator to be developed. It may be called a positive mu oscillator, because screen and suppressor circuits are in phase, so when phase signs are multiplied the sign is positive. With the usual type oscillator the plate and grid circuits in the tube are out of phase, and when the phase angles are multiplied the sign is negative. In the dynatron probably the phase is zero, as the mu does not directly enter.



A ray indicator tube is used, with deflection backwards, as resonance is denoted by widest instead of narrowest angle. If a dial is used that can be read to one-tenth division, hence one part in 1,000, as the one illustrated, a large curve may be drawn, and referred to with great accuracy for inductance measurements.

THE TUBE TERMINOLOGY

The present type of oscillator circuit is applicable to those tubes that have the suppressor independently brought out, such as the 57, 77, 6C6 and 6J7, the detector types being preferred as the oscillation is greater and more readily established. The oscillator is shown in the diagram in an unusual way, in that the tuned circuit is in the suppressor leg, whereas a fixed resistor is the load on the screen, and a mica condenser is used for

(Continued on following page)

(*Continued from preceding page*)

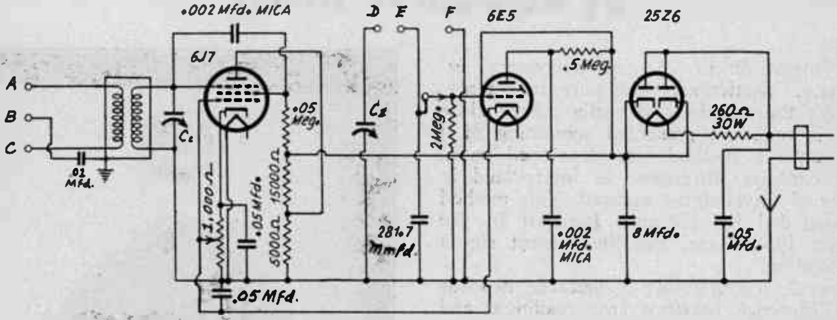
coupling. A capacity of .002 mfd. is indicated, but wide variations from this are permissible.

NOTE ON CONSTANCY

The tubes under discussion have cathode, control grid, screen, suppressor and plate, and these designations will be used, although in the oscillator really the suppressor is the control grid, the screen serves as the effective plate, the formal plate is not put to any use except d.c. potential application, and the usual control grid is simply a means of adjusting the amplitude by varying the negative bias on this element.

For oscillation to be well established it is necessary that the screen be returned to a positive voltage, and 100 volts or so are ample, whereas the plate has to be returned to a voltage somewhat less than one-third that applied to the screen. The resistance values as stated were found suitable, for amplitude-control grid returned to minus (negative bias about 2 volts).

The resistance values of the voltage divider, if any experimenting is to be done, should be selected on the basis of 1,000 ohms in the cathode leg, 20,000-ohm wire-wound potentiometer between B plus and line, plate connected to the arm, and arm adjusted until oscillation not only is present, but the direct cur-



A three-tube device for measuring radio-frequency inductance. A positive mu oscillator provides the output, calibrated in wavelengths squared. Coupling is established between the secondary at left and the output winding the coil AC. The unknown coil is inserted between E and F. A fixed condenser of critical capacity, 281.7 mmfd., is cut in and out, and the inductance is read on the oscillator condenser dial. For range extension, any large variable C_1 may be an adjunct of the unknown's circuit.

LIST OF PARTS

Coils

One shielded transformer, consisting of two loosely coupled 8 millihenry honeycomb choke r.f. coils.

Condensers

One National Company SEU-15 variable, 15 mmfd. maximum, to tune one winding of above transformer. (Condenser Cc in diagram.)
One variable condenser, .000365 to .0005 mfd. or larger capacity (C_1).
One 281.7 mmfd. precision capacity, consisting of a fixed mica condenser and air-dielectric trimmer across it, with switch the capacity of which is included in the reckoning.
Two .002 mfd. mica. Three .05 mfd. bypass. One .01 mfd. mica.
One 8 mfd. 175-volt dry electrolytic in cardboard container.
(The fixed condensers are products of Cornell-Dubilier.)

Resistors

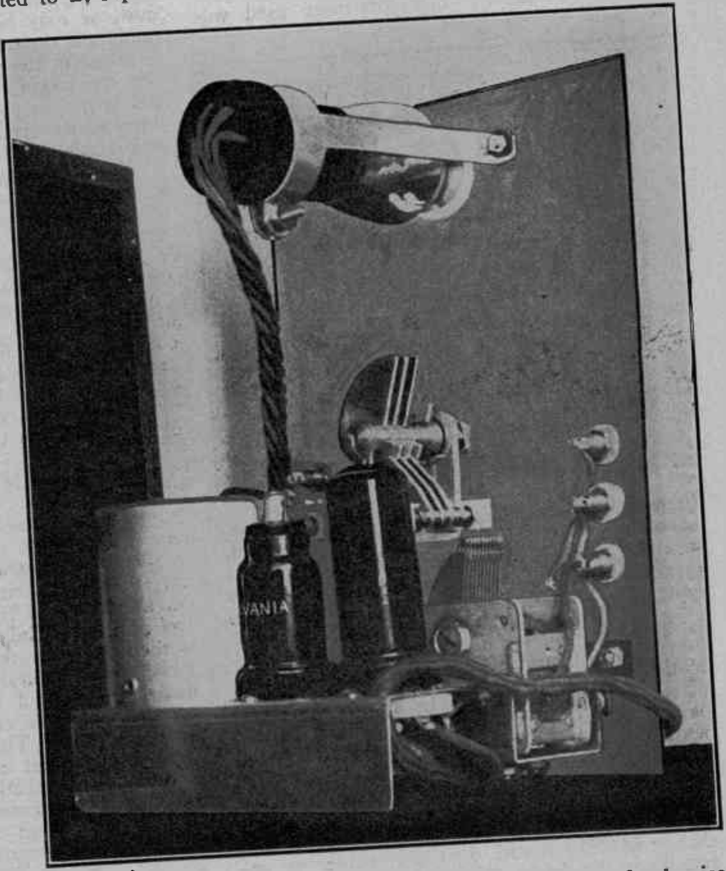
One 1,000-ohm wire-wound potentiometer with line switch attached.
One 5,000-ohm. One 15,000-ohm. One .05 meg. (50,000 ohms). One .5 meg. One 2 meg.
Fixed resistors, 1/3 watt or more. (All resistors products of International Resistance Company.)

Other Requirements

One line cord with 260-ohm, 30-watt resistor built in.
Six binding posts. One octal and two six-hole sockets.
Sylvania tubes: one 6J7, one 6E5, one 25Z6.
One National Company Type BX dial. One miniature grid clip.
Chassis, panel, shield box, three knobs.

ent through the cathode leg remains abso- utely constant as the tuning condenser across he coil is varied from maximum to minimum.

Only a single winding coil is needed for this ype of oscillator, but a secondary is shown as an output device. Since both terminals of this secondary are free, connection may be made to any balanced device, such as a doublet input to a set, in case harmonics of the generation are to be used for frequency measurements, as a side asset of the device. For such use with a doublet the terminals A and C are used, whereas for a Marconi antenna or other input with one side grounded, C is connected to B, representing ground, or A may be connected to B, and C is then used as the high side of the output.



The small condenser is the one that tunes the positive mu oscillator. The large one, lower right, is C_1, the range-extension condenser. Supplementary capacity may be included externally, if desired. An 8 millihenry coil tuned by the small condenser is in the shield can at left. The device was enclosed in a metal box, which was grounded, although tuning condensers, etc., were insulated from the metal box, since they go to one side of the line. A glance at the diagram will show the necessity of this precaution.

For inductance measurement a coupling means is required between the generator and the detector, which is a ray indicator tube. A large inductance honeycomb is connected with two leads long enough to enable coupling the honeycomb weakly to the coil to be measured. The honeycomb wire connections go to A and C, with either A or C connected to B, while the unknown coil, L_x, is connected between E and F. This is assumed to be a single winding.

If there are primary and secondary, the primary is connected across A and C, with B to either A or C, and the amplitude is kept always within the range of the visual detector by adjustment of the amplitude control. This variation also changes the bias on the ray tube. As the generator does not oscillate as strongly at zero bias as at a small negative bias, in fact, may not oscillate at all at zero bias, if it is assumed that the circuit does not work, it may require only that the control arm be moved a bit nearer the bottom.

THE CRITICAL CAPACITY

A switch is used for cutting in and out the critical capacity of 281.7 mfd., which is a commercial product, composed of a fixed mica condenser and a small variable across it, of the air-dielectric trimmer type, adjusted for high accuracy. If the condenser accuracy is high the only other thing to worry about is the calibration accuracy, and since a small range is used, this accuracy may be of the order of .25 per cent. All told, an inductance accuracy of half of one per cent. should be readily attainable.

It is clear that if the frequency generated by the oscillator is the same as that of the detector that the method applies readily. Since the actual capacity in the measured circuit is

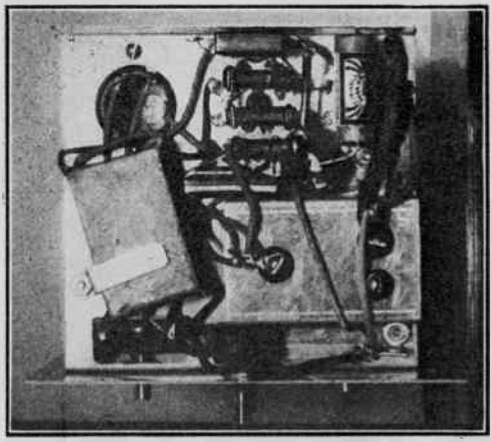
(Continued on following page)

(Continued from preceding page)

of no moment it may be increased, and a range condenser is therefore included, which may be .0005 mfd. maximum, so that inductances smaller than the one in the generator may be measured, using fundamentals. The advantage is that the response is more distinctly noted in the ray tube, which in this case, by the way, works backwards. Instead of narrowest angle, greatest angle is the notation condition.

ADDING EXTERNAL CAPACITY

Nevertheless, harmonics may be used, which would apply as the inductances become progressively smaller. The condenser used was National Company's SEU-15, which has six plates, maximum capacity 15 mmfd. The rest of the circuit accounts for about as much, so with 30 mmfd. and 8 millihenries as the tuned secondary, in the shield can, the lowest frequency generated was about 325 kc and the highest about 400 kc. Whatever the inductances lower than a few millihenries, if the change of 281.7 mmfd. does not enable two responses in the detector from the generator, then more capacity must be added to the test circuit. It has been noted that anything may be added. There is a built-in variable on this purpose, but more may be added externally. This variable is C_1 in the diagram, and is included by connecting with a wire the binding posts D and E. The 281.7 mfd. may be switched in and out independently, as it is switch-controlled. The switch has capacity that may have to be considered, as is done in the commercial unit, where the switch capacity is measured along with the rest so that the acutal accuracy is better than .3 per cent. The extra capacity externally included is put across the D and F posts.



Underneath view of the chassis. The filter condenser is at left. The larger object, lower right, with three screws in triangular alignment, is the range condenser C_1, which in this case was .000365 mfd. The 1,000-ohm potentiometer is the object at lower left, inside the chassis.

Besides the actual measurement of inductance, coils may be compared, where the desire is to find coils that are alike, where a standard is used. This standard may be any coil of a selected run. This standard is put into the oscillator circuit. The 281 mmfd. condenser is switched out of the circuit because not figuring in the present work, another similar coil to the standard is put between D and F, and a wire is run from the grid of the 6E5 to D.

CLOSE MEASUREMENTS

Then with the National condenser at maximum, C, which may be any small condenser, now, or may be a large condenser with small minimum, is turned until maximum deflection is noted in the ray index. If there is scarcely any movement, the minimum capacity of C_1 is too large, so some extra capacity may be put temporarily across the National condenser for equalization. Now when the resonance point is sharply established, other coils are tried across the oscillator until the same deflection is obtained, when the two inductances are deemed equal.

This, unlike the general inductance measurement, is not absolute, because the distributed capacity of one coil may be different from that of another, and apparent inductance alone is considered, yet for a given run this capacity difference will be small and negligible. The effect may be reduced further by using .00025 mfd. fixed capacity across the National condenser and using C at about equivalent capacity.

AN ENTERING WEDGE

For closest measurements in all instances, note the position of the attenuator that yields oscillation and steadiness of d.c. when a large variation of capacity is tried, e.g., a .00035 mfd. condenser across the National. Note this control position. The calibration of the frequencies is then made for this control position, also and when most accurate measurements are to be made, the control is put always at the same position, and the coupling to the unknown is altered to suit. This coupling always must be weak for greatest accuracy.

When the operation of this device becomes familiar to the constructor he will be able to tackle the problem of correct oscillator inductance for superheterodynes, as well as for r. f. and i. f. levels. This opportunity provides an entering wedge not previously handy to the service man.

The 12 Basic Equations

Ohm's Law Relates Wattage, Voltage, Current and Resistance

By Hood Astrakan

OHM'S law relates voltage, current and resistance. Since power depends on these it also includes power. The force that drives current is the potential, expressed in volts. Hence voltage is the term by which the potential is defined.

The driven agency is the current. This may be considered as the electrons that are moved under the influence of potential. The current represents the net drift of electrons, as some electrons neutralize others.

The resistance is the opposition offered to the flow of current. The resistance therefore limits the current.

The power is an expression of the amount of work done in unit length of time. It is necessary to have the time element understood, even though it is seldom expressed, because comparison of powers is significant only for the same durations of performance. The identity of the duration is understood, so the symbol t could be used for representing time. It is so used in meticulous formulas. Since in physics the work done is expressible as energy, power then may be defined as the time rate of energy.

Potential and resistance are independent of time, but since power has a time factor, some component of power must have one, too. The current component of power is the one. Current, even d.c., hence also requires that the time element t be understood. We write 100 milliamperes, but as current is a rate and every rate is related to time, 100 ma t would be the meticulous expression.

In the following twelve equations $W =$ watts of power, $E =$ volts of potential, $I =$ amperes of current and $R =$ ohms of resistance.

$$W = EI = I^2 R = \frac{E^2}{R}$$

$$E = IR = \sqrt{WR} = \frac{W}{I}$$

$$I = \frac{E}{R} = \sqrt{\frac{W}{R}} = \frac{W}{E}$$

$$R = \frac{E}{I} = \frac{E^2}{W} = \frac{W}{I^2}$$

Hence the above are the twelve equations of Ohm's law.

The need for accurate information on the construction of an effective shielded test room, in which the serviceman may fully utilize modern test equipment without interference from strong local fields of either man-made static or broadcasting stations, is met by a set of specifications just issued by the Tobe Deutschmann Corporation, Filterette Division, Canton, Mass. These specifications show the construction of a shielded test room approximately six feet square and enable the serviceman or any local builder to construct the shielded room without difficulty. In addition, a Filterette in the power supply line is used to keep disturbances from entering the test room by way of its power connection.

Measuring a Choke on Load

Inductance of Iron-Core Devices Determined, 2 to 60 Henries, with D.C. to 200 Ma Flowing

By Edward M. Shiepe

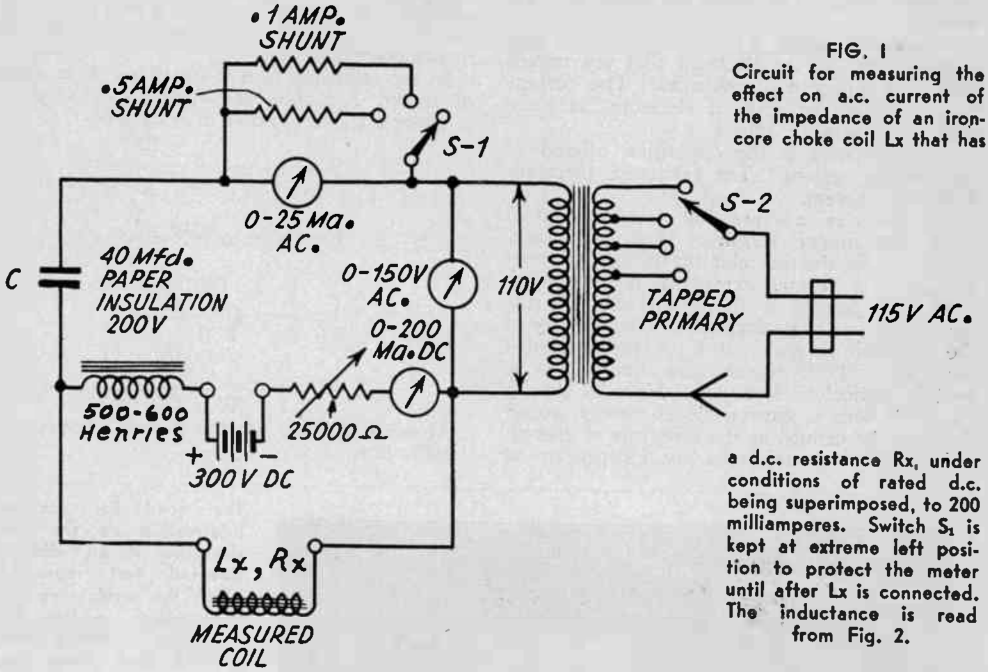


FIG. 1
Circuit for measuring the effect on a.c. current of the impedance of an iron-core choke coil Lx that has a d.c. resistance Rx, under conditions of rated d.c. being superimposed, to 200 milliamperes. Switch S_1 is kept at extreme left position to protect the meter until after Lx is connected. The inductance is read from Fig. 2.

THE inductance of a filter choke varies with the amount of the direct current component, and is less when that component is greater. It is often desirable to measure the actual inductance with a known direct current flowing through the coil, and a simple instrument for doing this is not now on the market. In the following, a reproducible method is presented, together with calibration curves, applicable to the circuit given when used with standard meters.

The range of inductance measurable is from 2 or 3 henries minimum to 60 henries maximum. Since chokes usually run from 7 to about 30 henries for the standard filter, the range of the instrument is seen to be amply sufficient.

Adjustment of the saturating d.c. component is made possible from 0 to 200 ma. This nicely encompasses the 80-125 ma drain common to the usual filter in a receiving set.

NEARLY DIRECT-READING

The instrument is made as nearly direct-reading as possible under the circumstances. To operate the instrument, the secondary voltage is adjusted to 110 volts a.c. after the choke has been connected in the circuit. If the ammeter reads .1 ampere or less, the switch S-1 is turned to the center tap or the extreme right for the best scale reading. The current flowing is noted and referred to Fig. 2 which interprets this into inductance directly.

In using Fig. 2, it is first necessary to measure the d.c. resistance of the choke, and this can be done with a commercial ohmmeter with sufficient accuracy for most cases. The d.c.

component is adjusted independently and read on the 0-200 milliammeter.

The principle employed in the instrument is the fundamental Ohm's Law for a.c. This is expressed by I = E/Z, where I is the current in amperes, E the voltage in volts, and Z the impedance in ohms. Z in this case is composed of resistance and inductance, while the frequency is taken as 60 cycles. The formula for this is $Z = (R^2 + (377L)^2)^{1/2}$ where 377 is equal to 2π times the frequency. In Fig. 2, we have a separate curve for each value of R, and instead of reading Z and calculating L from the known values of I and E, this is all done for us and we need only read the inductance from the curve. For the correct use of the instrument, therefore, we must be sure to maintain the secondary voltage at 110 a.c.

SEGREGATION OF CURRENTS

The circuit of Fig. 1 appears a little more complex than the above method seems to require. But the d.c. circuit must be made impervious to a.c. and likewise the a.c. circuit must be safeguarded from d.c.

The segregation of a.c. from the d.c. path is accomplished by the choke L, which is seen to be large, and d.c. is kept from the AC supply by the condenser C, likewise large. The larger each of these is, the more nearly correct will be the determination of the unknown inductance.

The secondary voltage of 110 volts was chosen because a higher one would require a condenser C which would be more difficult to obtain. The inductance L may be made up of, say, ten separate chokes in series, each having 50 henries inductance. This is better electrically than making a single choke of the required inductance, because the distributed capacity is considerably decreased, and this factor has some importance even at the low frequency involved.

ACCURACY IS 5%

The measurement will be accurate to within 5 per cent., if the values used are as shown in Fig. 1. This is determined largely by L and C in the diagram. The meters used may be small ones of 2 to 5 per cent. accuracy, and hence need not be expensive.

The d.c. component may be obtained from a power supply or from batteries. If a power supply has a slight ripple, the choke L will remove it.

Curves Solving Inductance by Separating D.C. Resistance from the Impedance

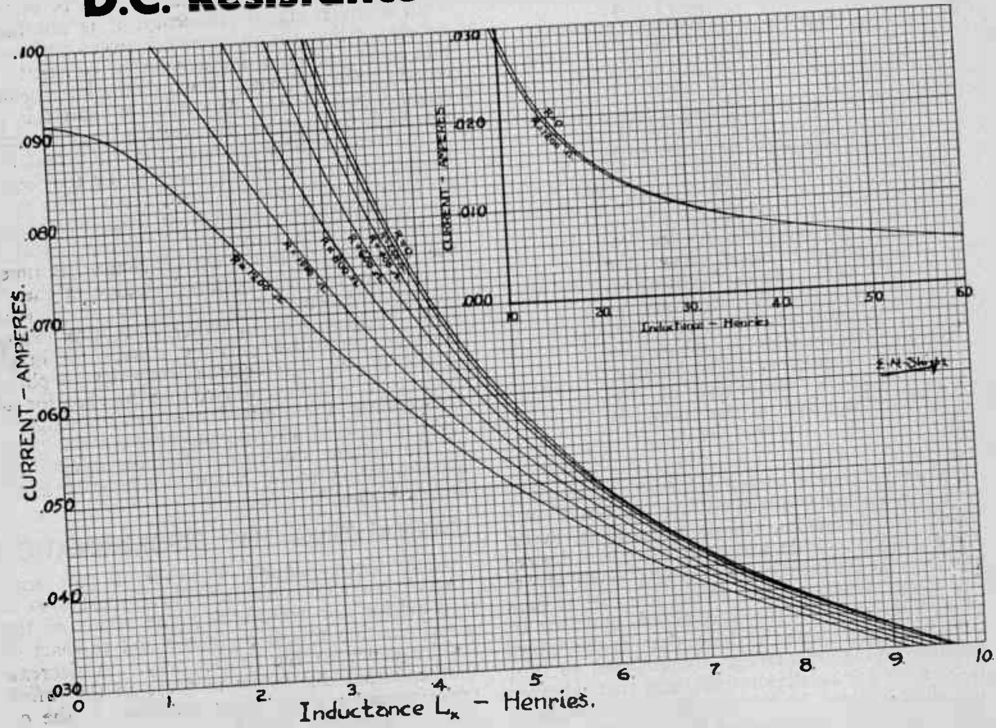


FIG. 2

Inductance in henries is read from this curve by obtaining the intersection of the a.c. current and d.c. resistance graphs. The inset carries the range of L to 60 henries. The data apply strictly and only to 60 cycles.

THE LATEST IMPORTANT DEVELOPMENT

Automatic Frequency Control

Expert Explanation of an Ingenious Method

By J. E. Anderson

AUTOMATIC frequency control (a.f.c.) is the newest wrinkle in radio receiver technique, the latest addition to the burdens of the service man, the most mysterious of the many mystifying "talking points" of the radio salesman. It is a sister wrinkle to the well-known a.v.c., for it is closely related to it in theory and function. This latest wrinkle has come to stay, for it serves a definite need, and the provident service man is doing well in asking for information that will help him master the principles of this innovation.

What is automatic frequency control? Well, it is an automatic tuning trimmer, a device by which a station is tuned in "on the nose," provided that the manual tuning control has carried the tuning to within about 10 kc of the desired station. It automatically corrects small errors in tuning, whether these errors are due to lack of skill or care on the part of the operator or to mechanical imperfections that make exact manual tuning impossible. In addition to this, it corrects for oscillator drift, and that whether the drift occurs in the transmitting oscillator or in the local oscillator of the receiving superheterodyne.

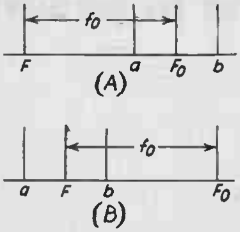


FIG. 1.
This illustrates on the frequency scale how the heterodyne frequency, $f = F_0 - F$, may vary as either of the two beating frequencies is subject to fluctuation. The intermediate frequency, as determined by the tuner, is denoted by f_0.

THE FREQUENCY REQUIREMENTS

The advantages of such automatic frequency alignment can be fully appreciated by those who have attempted to receive signals on ultra high frequencies in which the relative drift between the two oscillators is so great as to render steady reception of a station impossible. Such operators have long felt the need of a device which would force the local oscillator automatically to follow the signal at the proper distance. The a.f.c. device does that within a certain range of the signal frequency.

Following the signal at a proper distance means that the i.f. to which the superheterodyne is tuned should be equal to the difference between the station frequency and the local oscillator frequency. If the set is to be in tune with a given signal frequency, it is absolutely necessary that the difference between the signal and local oscillator frequencies be constant and equal to the frequency at which the intermediate channel was tuned. Any relative change in the two high frequencies will cause a large detuning in the intermediate channel, for the actual beat frequency will be either too high or too low to go through the sharply-tuned filter. The problem is to make the local high frequency change so that the beat frequency is always equal to the frequency to which the i.f. channel is tuned. It is clear that the required change in the oscillator frequency may be either an increase or a decrease, yet, in either case, this change must be controlled only by a *decrease* in the output of the intermediate frequency amplifier. Therefore, whatever device may be used for accomplishing the desired frequency change, it must be able to discriminate between the causes of the volume decrease. Besides having this discriminatory power, the device must be simple and economical.

CAPITALIZING THE DISCRIMINATION

Mere discrimination, however, is not sufficient in an a.f.c. system. There must also be a provision for transferring the result of this discrimination to the oscillator and to react on its frequency in the proper way. A decrease in the output due to an increase in the difference frequency must effect a change in the oscillator frequency which in turn results in a decrease in the difference frequency. Conversely, a decrease in the output due to a decrease in the difference frequency must change the oscillator frequency so as to increase the difference frequency. In every case the difference frequency must be pushed or pulled back to its optimum value, or as near to that as an automatic balancing device can effect it.

What change in the local oscillator frequency is necessary to offset a given change in the difference frequency? Will the same device keep the difference frequency constant regardless of which of the two beating frequencies changes, that is, the signal frequency or the local oscillator frequency?

Let us investigate this briefly for the case of a superheterodyne in which the local oscillator frequency is higher than the signal frequency.

WHEN LOCAL OSCILLATOR IS TOO HIGH

Let F be the signal frequency, F_o the oscillator frequency, and $F_o - F = f$ the difference frequency. Let f_o be the optimum value of f, or the frequency to which the intermediate filter has been tuned. In the first case, Fig. 1A, let F remain fixed and let F_o be subject to variation between the limits *a* and *b*. This case covers mistuning and local oscillator fluctuations. Suppose that F_o is low, toward *a*. Then f is low, and to bring the circuit in tune it is necessary to increase F_o. Or, suppose that F_o is high, toward *b*. Then f is high, and it is necessary to decrease F_o. In the second case, Fig. 1B, let F_o remain relatively fixed and let F be subject to variation between the limits *a* and *b*. This covers cases of unsteady transmitting oscillators. Suppose F is low. Then f is too large, and it is necessary to decrease F_o. Suppose that F is high. Then f is low, and it is necessary to increase F_o. In both cases we note that when f is low F_o must be increased, and when f is high F_o must be decreased. Thus the same correcting device will compensate for tuning errors regardless of where they arise.

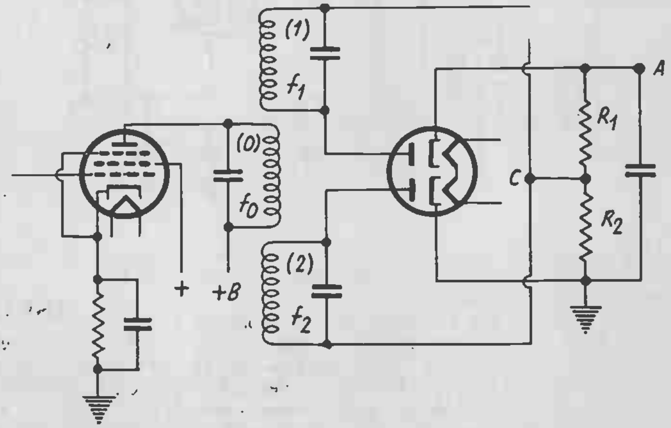


FIG. 2.
A discriminator circuit in which two tuned circuits are coupled to a third, which is tuned to the signal frequency. The two circuits tuned to f_1 and f_2 are called side circuits, one being tuned to a frequency higher than f_o, the other to a frequency lower than f_o.

TRI-TUNED DISCRIMINATOR

What kind of device will discriminate between two output voltages or powers when they differ only in that they are produced by detuning a circuit in opposite directions? The only definite difference is that of phase, in the voltage or current, and the device must depend on phase differences.

The first discriminator circuit to come to mind is the one employing two side circuits and tuned to slightly different frequencies, and both different by equal amounts from the desired frequency. A discriminator of this kind is illustrated in Fig. 2. A signal of frequency f_o is delivered to the tuned circuit (O), which is tuned to f_o. Coupled equally to this circuit are two other similar circuits (1) and (2) which are tuned to frequencies f_1 and f_2, respectively. The three frequencies are related in such a way that $f_o = f_1 + df = f_2 - df$, in which df is one-half the frequency range over which the device is to operate.

It will be assumed that the two rectifiers entering into Fig. 2 are substantially equal so that for equal input voltages the output voltages across the two equal load resistance R_1 and R_2 will be equal. Now let difference frequency f be equal to f_o. Then equal voltages will be induced in (1) and (2), for the two circuits will be detuned by the same amount, one below its natural frequency and the other above its frequency. The output voltages will also be the same. Since these are added in opposition, the net voltage between ground and the point A will be zero.

Now let the difference frequency become less than f_o. The signal will then induce a higher voltage in circuit (1), for f will be nearer to f_1 than to f_2. Therefore the voltage across R_1 will be higher than the voltage across R_2. The point A will therefore become positive with respect to ground, the amount depending on the degree of detuning.

If the detuning is in the opposite direction, toward f_2, the voltage across R_2 will exceed that across R_1, and consequently the point A will become negative with respect to ground. This arrangement might be used, therefore, to vary the bias of a tube in either direction about a mean value. The voltage output of the device could also be used for unbalancing, in either direction of a push-pull, direct current amplifier having a polarized relay in its load circuit. This relay in turn could change the frequency.

The circuit in Fig. 2 is not regarded as desirable for reception because, first, it has two

(*Continued on following page*)

(*Continued from preceding page*)

secondary tuned windings instead of only one and, second, neither of these secondaries is tuned to the i.f. signal frequency. The arrangement, therefore, cannot be used simultaneously for detection, a.v.c, and a.f.c.

A SIMPLIFIED DISCRIMINATOR

The arrangement in a simplified discriminator which has been incorporated in commercial receivers is shown in Fig. 3. The intermediate carrier is delivered by the first tube to the tank circuit (1), which is tuned to f_o. The coil of this circuit is coupled loosely to another circuit resonant to f_o. The top point, (a), of the first circuit is connected to the midpoint, (b) of the second circuit, through a condenser C_1. The second circuit, (2), is connected to the plates of two diode detectors. The voltage at the point A in respect to point B will be either positive or negative, depending on which way the resonant circuits are detuned.

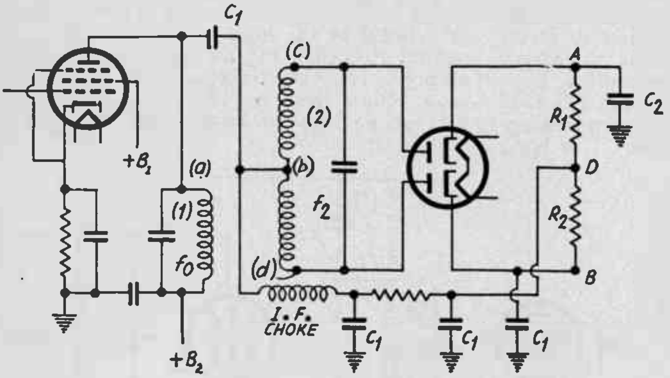


FIG. 3.
A discriminator circuit in which two resonant circuits, both tuned to the signal frequency, are used. The discrimination in this case is obtained by adding, vectorially, the voltage across the primary to the two half voltages of the secondary.

The truth of this statement is not apparent, but a little analysis confirms it. Condenser C_1 between (a) and midtap (b) is supposed to be so large that the voltage drop in it is negligible. That is, the two points are at the same potential. Now, the phase of (a) with respect to ground potential is zero when the difference frequency has the value f_o, for at resonance there is no phase shift in the tank circuit. Thus the point (b) is at zero phase.

The current in (1) induces a voltage in (2), and this is distributed equally about the midpoint (b). At a given instant point (c) is as much positive as point (d) is negative.

ZERO POTENTIAL DIFFERENCE

The voltages impressed on the two rectifiers are therefore equal, although opposite in phase. The rectified outputs depend only on the magnitudes and hence the voltage drops across R_1 and R_2 will be equal. Since the two rectifiers are connected in series opposing, the potential difference between A and B will be zero. This balance occurs only when the frequency is equal to the resonant frequency of the two loosely coupled i.f. circuits.

Suppose now that the signal frequency differs considerably from the resonant frequency. There will then be a phase shift of nearly 90 degrees in the circuit. The voltages induced in the two halves of the secondary are still equal in magnitude and opposite in phase with respect to (b). The voltage drop across (1) is now added vectorially to the induced voltages. Thus the potential at one side of the secondary, say (c), will be the sum of the induced voltage (bc) and the drop voltage across (1), while the potential of the other side, (d), will be the difference between the drop in (1) and the voltage induced in (bd). The potential is measured with respect to ground, for the primary circuit is grounded to a.c. on one side. The cathodes of the two rectifiers are also grounded with respect to a.c. It follows that the input voltage of one rectifier, the upper in the assumed case, is much greater than that in the other. Therefore the voltage drop in R_1 will be greater than that in R_2, and A will be positive with respect to B.

THE CONTROL CIRCUIT

When difference frequency is such that the resonant circuits are detuned in the opposite direction, the same argument leads to the conclusion that A is negative with respect to B. Therefore, depending on the sense of the detuning, the point A can assume either a positive or a negative potential with respect to B. The magnitude of this potential depends on the amount of detuning. The next part of the problem is to make use of his discrimination to change the frequency of the oscillator.

The frequency control circuit and the oscillator are shown in Fig. 4. The oscillator is more or less conventional for it has only minor modifications to adapt it to the frequency control. The padding condenser C_p is put in the high potential lead where it serves three functions, namely, grid blocking, plate blocking, and resonator padder. C_2 is only a bypass condenser from B plus to ground.

The control circuit proper consists of the tube to the left, the resistors R_1 and R_2, and the condensers C_1 and C_2. It amounts to a reactive impedance in shunt with the oscillator coil L.

A simplified arrangement of the control circuit, together with the remainder of the oscillation circuit, is shown in Fig. 5. In this C_1 and

R_1 have been omitted because their values are such that they do not change the total effective impedance shunting L. That this impedance is inductive is easily demonstrated without mathematics.

A certain voltage E_p, exists across the tuned circuit, or across L. The same voltage exists across R_2 and C_2 in series and also across the control tube. If R_2 is a high resistance, the current through it is nearly in phase with E_p. The voltage across C_2, however, will be nearly 90 degrees behind E_p. That is, the grid voltage on the control tube lags the plate voltage on that tube. But the plate current is in phase with the grid voltage. Therefore the plate current lags behind the plate voltage nearly 90 degrees.

In an inductance of low resistance the current also lags 90 degrees behind the voltage. Therefore the control circuit, as arranged in Fig. 4, amounts to an inductance with a small resistance in series with it. This inductance is in shunt with the inductance in the oscillating circuit, and hence it reduces the effective inductance. Therefore it increases the frequency of oscillation.

SAMPLE FORMULAS

The amount by which it increases the frequency can be estimated. If small terms are neglected, the analysis of the circuit leads to the conclusion that the effective inductance of the control circuit is given by $L_p = R_2C_2/g_m$, in which g_m is the mutual conductance of the control tube. If this inductance be combined with the coil inductance L, the total effective inductance in the oscillator circuit is

$$L_e = LR_2C_2/\,(Lg_m + R_2C_2). \qquad (1)$$

Then if K is the total effective capacity across the inductance, the frequency is given by

$$\omega^2 = \frac{1}{L_eK} = \frac{1}{LK}\left(1 + \frac{Lg_m}{R_2C_2}\right)$$
$$= \omega_o^2\left(1 + \frac{Lg_m}{R_2C_2}\right) \qquad (2)$$

Since the second term in parentheses is small compared with unity, this equation can be written

$$f = f_o\left(1 + \frac{Lg_m}{2R_2C_2}\right) \qquad (3)$$

in which f_o is the frequency of oscillation when the control circuit is disconnected.

This formula shows that the change in frequency is proportional to the mutual conductance of the control tube. Since g_m can be varied over rather wide limits by means of grid bias variations, the arrangement provides a means for varying the frequency with the discriminator circuit previously described. The range of frequency change for a given grid bias change depends on the inductance L, on the frequency f_o, and on the product R_2C_2. If the bias on the tube is high enough, the mutual conductance will be zero, and if the bias is near zero in a tube like the 6J7 the mutual conductance is about 1,200 micromhos. This large change in the mutual conductance is effected by a change in the grid bias of less than 6 volts. Suppose that the tube has a mutual conductance of 1,000 micromhos when g_m is greatest. Also assume that $f_o = 1{,}000$ kc, $L = 140$ mmfd., $R_2 = 70{,}000$ ohms, and $C_2 = 20$ mmfd. Under these conditions, the frequency increment, as given by equation (3), is 50 kc. At 550 kc it is 27.5 kc and at 1,500 kc, 75 kc.

In a control circuit the mean bias on the grid would be chosen so that the change in g_m for a given change in bias would be most rapid, and also so that there would be approximately equal frequency changes on both sides of the mean. The control tube used should be one of the quick cut-off, high-mu tubes, such as the 6J7, the 57, and the 6C6, and the like.

Formula (3) is not exact, for it was derived by making many assumptions and approximations. It was assumed, for example, that the grid and plate resistances of the oscillator tube had no effect on the frequency, that the resistance in the coil L and the effective inductance of the control tube were zero, and the current through R_2 and C_2 was negligible in comparison with the current through the mu-

(*Continued on following page*)

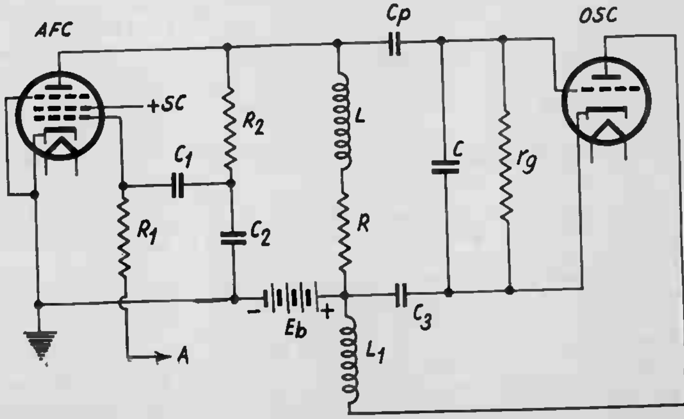


FIG. 4.
An oscillator coupled to an AFC tube in which the effective value of the inductance L is varied by varying the mutual conductance of the AFC tube with the bias voltages generated in the discriminator.

(*Continued from preceding page*)

tual conductance g_m. Notwithstanding this inexactitude of the formula, it is sufficiently accurate for design purposes.

CONNECTING THE TWO PARTS

When the frequency of the oscillator in Fig. 4 is to be controlled by the discriminator in Fig. 3, point B is connected to the negative of the fixed bias for the control tube. If no bias is used, or if there is self-bias, this point is ground. In other cases it may be a point on a common voltage divider.

In every case point A of Fig. 3 is connected to point A on Fig. 4.

The range of bias values available from the discriminator depends not only on the amount of unbalance but also on the intensity of the signal at the detector, because, for any given unbalance of the discriminating circuit the output of each rectifier will be proportional to the signal intensity. Therefore the difference between them, which is the control bias, will also be proportional to the signal intensity. The bias might become necessarily large. To prevent this there should be adequate a.v.c. in the circuit.

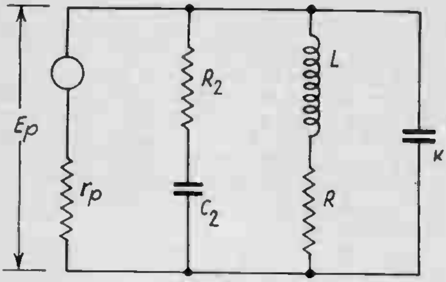


FIG. 5.
The equivalent of the oscillator section of Fig. 4 when all elements unessential to the analysis have been eliminated.

Of course, it is not necessary to use all the control bias available for controlling the tube and the frequency. It is also possible to adjust for different intensities by changing the product R_2C_2. As will be noticed by examining formula (3), the frequency range of control varies inversely as this product. By making it large, the range is narrowed; by making it small, it is widened. By proper choice of R_2C_2 can be made to fit the required conditions in any given case.

EFFECTIVENESS OF CONTROL

The frequency control can never be perfect, because there must be some discriminator unbalance before the action can take effect. All that the arrangement can do is to bring the tuning closer to the peak than the manual control leaves it, or than the oscillator fluctuation leaves it. It can never bring the tuning to maximum. But this fact is of little practical importance, for the control might bring the tuning 500 to 1,000 times closer. That is, if the mistune amounts to 10,000 cycles, the control will bring the tune to within 10 or 20 cycles. That is close enough in all circuits intended for audio signals. Of course, it may not be practical to make the control ratio as high as 1,000, though even 500, or in fact 100, that is satisfactory.

It is clear that the effectiveness of the a.f.c. is not the same at all frequencies. The discrimination power remains the same for all signal frequencies, as long as the i.f. is the same, but the frequency change due to a given bias change varies with the signal frequency. In fact, the change in frequency is directly proportional to the signal frequency. Therefore as the frequency increases, the change in the frequency might become comparable with the intermediate frequency, whereas for best results it should only be about as wide as the resonance curve of the i.f. filter. The way to narrow the band, as has already been pointed out, is to increase the value of R_2C_2. When different coils are used for different bands of signal frequency, the width of the frequency band would be about the same for all bands even if the R_2C_2 remains unchanged, because narrowing of the band is effected by the decrease in the inductance.

The percentage of frequency control decreases as the frequency increases. Thus at broadcast frequencies the control range might be as much as 10 per cent, whereas at 10 megacycles it might not be more than 1 per cent. Yet the absolute width of the range would remain constant.

DETECTOR AND A. V. C.

It will be observed that the discriminator circuit in Fig. 3 can be used not only for a.f.c. but also for a.v.c. and audio. Point D is always negative with respect to point B. Hence this point corresponds to the negative end of the load resistor in the plain detector, and the grids to be volume-controlled are to be connected to this point. The audio signal voltage can also be taken off this point, or from any point on R_2 between D and B. Indeed, R_2 may be the audio volume control potentiometer. For good audio output the by-pass condenser connected to D should not be too large, say not over 100 mmfd., assuming that R_2 is of the order of half megohm.

All are now familiar with the fact that in a receiver provided with a.v.c. there is an apparent drop in selectivity. There is a similar effect in a receiver provided with a.f.c. In a.v.c. the output is nearly the same over a considerable frequency band about the desired station because as the tuning approaches the resonance point the a.v.c. becomes more and more effective. In a.f.c. the effect is similar because the oscillator frequency goes to meet the signal frequency. It also accompanies it a short distance on departure. One might almost describe an oscillator equipped with a.f.c. as being sociable.

In view of this apparent lack of selectivity it is necessary to disconnect the a.f.c. circuit during preliminary adjustments of the receiver, such as padding, trimming, and tuning the i.f. filter. And the a.f.c. must be disconnected in

Derivation of Formulas

The oscillating circuit in Fig. 4 can be simplified into the circuit shown in Fig. 5. Across this exists a certain alternating voltage E_p. The current through R_2 and C_2 is

$$I_2 = \frac{E_p}{R_2 - j/C_2\omega} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The grid voltage on the control tube is the voltage across condenser C_2, or $E_g = I_2/jC_2\omega$. With the aid of (1) this can be written

$$E_p = \frac{E_p}{1 + jR_2C_2\omega} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Therefore, if g_m is the mutual conductance of the tube, the plate current is

$$I_p = \frac{g_mE_p}{1 + jR_2C_2\omega} \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Hence the impedance of the electron path is

$$Z_p = \frac{1}{g_m} + \frac{jR_2C_2\omega}{g_m} \quad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

which is inductive since the reactive term is positive.

In shunt with Z_p is the impedance $R_2 - j/C_2\omega$. By combining this with Z_p and neglecting the resulting resistive term, we have for the effective reactance across the oscillating circuit

$$L_s\omega = \frac{C_2\omega(R_2g_m - 1)}{g_m^2 + C_2^2\omega^2} \quad \ldots\ldots\ldots\ldots\ldots(5)$$

If the resistance in L be neglected, L_s may be combined with L with the formula $L_e = LL_s/(L + L_s)$. This yields for the inductance of the oscillating circuit

$$L_e = \frac{LC_2\,(R_2g_m - 1)}{L(g_m^2 + C_2^2\omega^2) + C_2(R_2g_m - 1)}. \quad \ldots\ldots\ldots(6)$$

If K is the effective capacity in the oscillating circuit, L_e, as given in (6), yields the following for the frequency squared

$$f^2 = \frac{f_o^2[Lg_m^2 + C_2(R_2g_m - 1)]}{C_2(R_2g_m - 1 - C_2/K)} \quad \ldots\ldots(7)$$

in which f_o is the frequency of oscillation of the circuit when the control tube is not connected to the coil.

Only a negligible error is committed by neglecting unity and also $1 + C_2/K$ compared with R_2g_m. With this approximation (7) reduces to

$$f^2 = f_o^2\left(1 + \frac{Lg_m}{R_2C_2}\right) \ldots\ldots\ldots\ldots\ldots(8)$$

Now, the second term within parentheses is very small compared with unity. Hence we can write

$$f = f_o\left(1 + \frac{Lg_m}{2R_2C_2}\right) \ldots\ldots\ldots\ldots\ldots(9)$$

such a manner that there is no appreciable change in frequency. This is best done by opening the grid lead going to A and grounding it, or connecting it to the mean grid bias for the control tube. In making this preliminary change the object is not to render the variable term in equation (3) zero, but rather to make it constant at its mean value.

INDUCTIVELY FED CONTROL TUBE

Since the control circuit as given in Fig. 4 is a bit complicated, one naturally turns to the possibility of using inductive coupling between the oscillator and the control tube. At first thought it appears as if this would simplify the control circuit considerably. This possible simplification is clearly brought out by the control circuit in Fig. 6. Here the grid of the control tube, at the left, is excited by the voltage induced in a small winding L_2 by the current flowing in the oscillation coil L, the two windings being coupled by means of a small mutual inductance M.

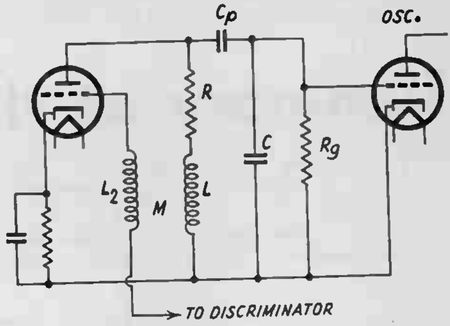


FIG. 6.

A tentative circuit in which the grid of the AFC tube is coupled inductively to the oscillator coil. Too great frequency variations result.

In this case the current through L lags behind the voltage across it by nearly 90 degrees. The induced voltage in L_2 is in phase with the primary current if M is positive and in opposite phase if M is negative. Hence the current through the tube is either in phase or in opposite phase with the voltage. Thus this arrangement is equivalent to a resistance across the coil. However, if R in the coil is high, there is an appreciable component of the primary current that is in phase with the voltage. If M is positive, this component induces a leading voltage component in the grid circuit, and there results a leading current component in the anode circuit.

In other words, the arrangement is equivalent to the addition of a capacity in shunt with the coil, or with the oscillator capacity. This added capacity is equal to g_mM/R, and is to be added to the capacity of the oscillator circuit.

FIG. 4 CIRCUIT PREFERABLE

Unfortunately, this produces an effect on the frequency that is greater than the effect of the original tuned circuit. This is easily checked

(Continued on following page)

(*Continued from preceding page*)

Suppose R is 25 ohms, M = 25 microhenries, and $g_m = 1{,}000$ micromhos. Then the tube adds an equivalent capacity of .001 mfd. to a capacity of only about 150 mmfd. It is obvious that the arrangement is not practical.

To make it practical the effective capacity would have to be reduced to about 10 per cent of the circuit capacity, that is, to about 15 mmfd. It could be reduced in increasing R, but if this is done the oscillation becomes feeble and the circuit might stop oscillating entirely. It could be done by reducing M, but this, too, has limitations. Finally, it could be done by reducing g_m. The first step would be to choose a tube with as low a mutual conductance as possible. Then a resistance of suitably high value could be connected between the plate of the tube and the top of the oscillator coil. There is also the possibility of reducing the grid voltage by means of a voltage divider. That this will work is not apparent in the formula, but it has the direct effect of reducing the mutual conductance as seen from the grid. But this voltage divider complicates the circuit, and the only object for using mutual inductance for coupling is nullified. The circuit shown in Fig. 4 is therefore preferable.

The discriminator circuit shown in Fig. 2 can be used for varying the frequency of an oscillator like that in Fig. 4 in exactly the same way as the discriminator in Fig. 3. Its only drawback is that another detector is required for the a.v.c. and the audio. A side circuit discriminator has also been used for varying the frequency electro-mechanically. A balanced relay is put in the output circuit of the dual rectifier in place of the two resistances, and the armature of that relay carries the plate of a small condenser which is in shunt with the coil of the oscillator. When the relay is unbalanced in one direction, the capacity in the circuit is too small but the relay acts to increase it. When the relay is unbalanced in the opposite direction, the capacity in the circuit is too large, but the relay acts to decrease it. The net effect is exactly the same as if the frequency of the oscillator were controlled by means of mutual conductance change as in Fig. 4.

Summary of the A.F.C. Process

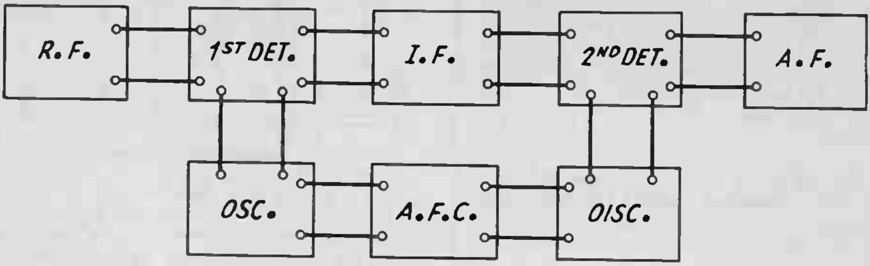


FIG. 7

Block, or functional, diagram of a superheterodyne equipped with automatic frequency control. The discriminator, coupled to or part of the second detector, affects the bias of the a.f.c. tube and through that the frequency of the oscillator.

The principles involved in automatic frequency control can more easily be comprehended with the aid of a block, or functional, diagram such as that in Fig. 7. The first element is the radio-frequency amplifier and tuner. Then follows the first detector or mixer. To one side of the mixer is the oscillator which supplies the local frequency. Following the mixer is the intermediate-frequency amplifier and selector. Then follow the second detector and audio amplifier in the usual order.

As an offshoot from the second detector is the discriminator circuit, the circuit that produces either a positive or a negative bias according to the direction in which the intermediate heterodyne frequency is off intermediate frequency resonance. This variable bias is impressed on the tube in the frequency control circuit, and this tube in turn varies the frequency of the local oscillator.

In this block diagram the second detector and the discriminator are shown as separate parts of the circuit. Actually in a practical circuit equipped with a.f.c. these two functions are performed by the same circuit in which there is only one tube. In addition to the audio-frequency signal and the a.f.c. bias, the a.v.c. voltage is taken from this circuit. The first detector and the oscillator are shown to be separate. They need not necessarily be, except the two tuners. The same tube may be used for oscillator and first detector, provided that the tube used has the proper characteristics.

THE VOLTAGE DIFFERENCES

Some may experience difficulty in understanding the manner in which the discriminating circuit functions, particularly how one rectifier gets more voltage than the other. Some assistance in understanding the problem may be had from Fig. 8. In (A) of that figure the tank voltage is represented by OA and the total

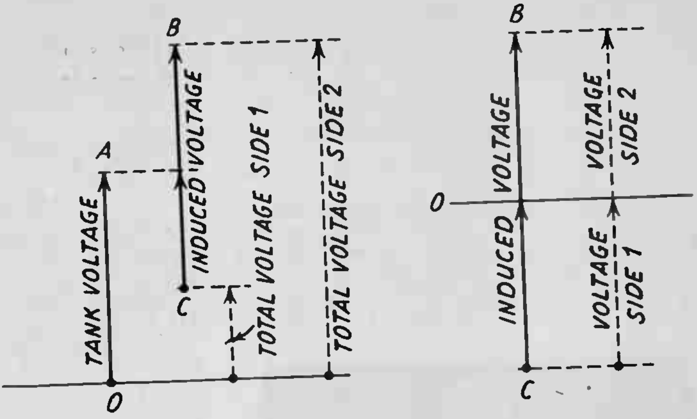


FIG. 8

This illustrates vectorial addition of the tank and the induced voltages when the circuit is detuned, at (A), and when it is in tune, at (B).

induced voltage in the secondary by CB. Since the tank is connected to the middle point of the secondary, the voltages add up differently in the two halves of the secondary. In one the total voltage is OA + AB, or OB. In the other the addition is OB + AC, or OC. The point O represents ground. It is clear that OC is much smaller than OB, and that one rectifier gets more input.

The situation at (A) Fig. 8 obtains for a given amount of detuning. The case of no detuning at all is represented at (B). The tank voltage now is zero and the ground is connected to the center point. That is, points O and A coincide. The two rectifiers now get equal voltages, and their rectified and filtered outputs are equal. The net a.f.c. voltage is zero because the outputs are added in series opposition. The statement that the tank voltage is zero in the balanced case needs explanation, for it is a fact that at the frequency of balance the tank voltage is maximum. But that voltage is at right angles to the induced voltage and when the vectors are added the tank voltage produces no effect on the induced voltage. It neither adds to nor detracts from it.

THE REVERSAL PICTURED

When the frequency is such as to detune the circuit in the opposite direction from that represented in Fig. 8 (A), the tank voltage has the opposite sign but the induced voltage has the same sign. This is equivalent to the case when the tank voltage is as in Fig. 8 and the induced voltage is reversed.

The situation can be imagined by rotating the line BC about the dotted, horizontal line passing through A. Another way of noting the effect of the reverse detuning is to leave Fig. 8 (A) as it is except that the side numbers are reversed. What now is side No. 1 becomes side No. 2, and vice versa.

Two A.F.C. Alignment Methods

Automatic frequency control is used in several models of General Electric receivers, and a brochure is issued covering the colorama dial and a.f.c. In this brochure, written by Hubert R. Shaw, data on a.f.c. alignment are given. These apply to the G. E. receivers. A cathode-ray and a meter method are discussed as follows:

CATHODE-RAY METHOD

The use of cathode-ray equipment for alignment of the i.f. system and adjustment of the a.f.c. trimmer is strongly recommended.

A cathode-ray oscilloscope of the usual type may be used in conjunction with a *frequency* modulated signal generator supplying a 465 kc signal. No audio frequency modulation should be used. Apply this signal to the grid of the first i.f. amplifier tube through a .05 mfd. capacitor. Connect the vertical plates of the oscilloscope across from ground to the center-point between the two diode load resistors. Set the tuning dial indicator at the low end of the broadcast band at some point where no signal is received since an extraneous signal might interfere with the aligning process. The volume control should be in an "off" or nearly off position. Place the a.f.c. switch in the "off" (counter-clockwise) position and proceed to align the primary and secondary of the second i.f. and a.f.c.-i.f. transformers (four trimmers). The object should be to make the two curves coincide with each other at the top and throughout their length with the maximum amplitude obtainable. This will require that all four i.f. trimmers be adjusted in the usual manner *excepting the a.f.c. secondary (hexagonal nut) trimmer which must be adjusted for minimum amplitude* before the curves will coincide properly.

Apply the same signal to the grid of the converter tube through a .05 mfd. capacitor as before. Adjust the primary and secondary trim-

(Continued on following page)

(Continued from preceding page)

mers of the first i.f. transformer until the curves obtained on the oscilloscope coincide as before.

A further adjustment of the a.f.c. secondary (hexagonal nut) trimmer is necessary in order to complete the i.f. alignment satisfactorily. This adjustment is as follows.

Apply the *same* signal to the grid of the second i.f. amplifier tube.

Disconnect the large capacitor across the extreme ends of the diode load resistors and connect the vertical plates of the oscilloscope between ground and the top end of the top diode load resistor (one side of the a.f.c. switch). With the a.f.c. switch in the "on" position, carefully adjust the a.f.c. secondary trimmer until the two sides of the curve are approximately symmetrical and intersect exactly at the axis as shown in Fig. 9. No adjustment of any other i.f. trimmers should be made at this time.

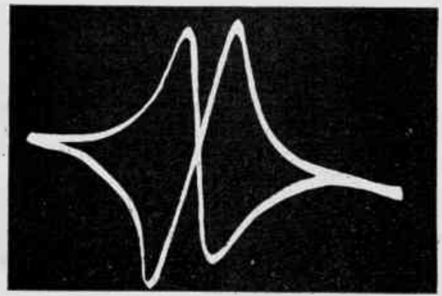


FIG. 9

For alignment the two sides of the curve should be approximately symmetrical, as in this oscillograph.

If a metal aligning tool is used, the curve will change when the tool is withdrawn. Therefore, it is advisable to use a fibre hex-headed wrench for this aligning adjustment. At any rate, the final curve should be as shown, with aligning tool removed.

METER METHOD

Although the use of the cathode-ray oscillograph for alignment purposes is to be preferred, it is possible to make the a.f.c. trimmer adjustments with reasonable accuracy using a 465 kc signal generator.

Place a modulated signal of 465 kc on the grid of the last r.f. (6K7) tube with the volume control set at maximum and the a.f.c. switch turned off. Place a low range a.c. voltmeter or other output indicator across the voice coil of the loudspeaker. Adjust the output of the signal generator so that an indication of not more than two or three volts is obtained on the output meter.

Adjust and readjust the primary trimmer for maximum output and *the secondary for minimum output*. This latter adjustment will be very broad. Apply the signal input to the grid of the first i.f. (6K7) tube and adjust both primary and secondary trimmers for maximum output; reducing the input as necessary to obtain approximately the same output indication as before. Apply the signal input to the grid of the converter (6A8) tube and adjust both primary and secondary trimmers for maximum output indication in the same manner as before.

It is now necessary to make a fine adjustment of the secondary trimmer of the last i.f. (a.f.c.) transformer.

Coaxial Cable and Relays Tried for Television Use, Says Lohr

By Lenox R. Lohr

President, National Broadcasting Company

At last television is out of the laboratory and into the field, undergoing tests which will assure that it does not reach the public until it is capable of satisfactory service.

The role of the National Broadcasting Company in television will be operating transmitters, programming, and, when it becomes available for commercial use, obtaining sponsors. In order that we may be prepared to do our part, our engineers are daily putting apparatus on the air under practical service conditions. Our program department is learning an entire new technique in continuity writing, make-up, staging, and a multitude of other details which this new art will demand. It is experimenting with commercial programs to determine the effectiveness of television to sell goods.

Our engineers are studying the economics of networking, so that several stations may be interconnected by either coaxial cable or short-wave relays, and are developing equipment for the making of outside pick-ups.

With the experience that we are gaining daily, we feel that when the time is ripe to offer television to the public, the National Broadcasting Company will be prepared to do its part.

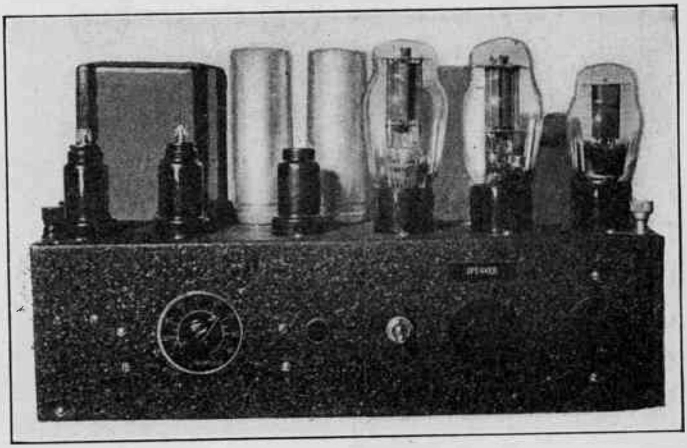
For information on the advances in television as shown in the recent RCA demonstration, see articles beginning on page 36, and illustrations on front cover and pages 34 and 35. The statement of David Sarnoff, president of RCA, begins on page 36.

A 30-Watt, 120 DB Amplifier

Even Crystal and Ribbon Microphones Swing 6L6G Push-Pull Output

By Harvey E. Sampson

Harvey Radio Co., New York.



Front view of the Harvey 137 amplifier, showing the arrangement of the tubes, filter elements, and the power transformer. The neat design is the work of Leo Speiser, one of the author's business associates.

HERE is a power amplifier designed especially for public address purposes. It consists of two stages of single-sided resistance coupled amplification and one stage of push-pull, together with signal divider tube and a power supply. No transformer or choke is used for coupling before the final output transformer which matches the power tubes' impedance to that of the voice coil.

The signal divider circuit deserves special mention. It is not of the usual phase inverter type, but is strictly a signal divider. Ordinarily, it is not possible to divide the signal in the proper way for push-pull amplification without killing one side of the circuit, but in this case it is accomplished by the simple expedient of lifting the cathode of the divider tube to a higher voltage.

Stated in another way, the feat is accomplished by dividing the total load resistance into two equal parts and inserting the B supply between them.

BIASING THE GRIDS

The cathode of the 6C5 is virtually grounded but not conductively. The negative end of the self-bias resistor, which would ordinarily be grounded, is at a high potential and is connected, through a stopping condenser, to the grid of one of the power tubes.

Control of volume is effected in two ways. First, there is provision for eliminating the first stage entirely. There are three input binding posts, one common, one for low gain, and one for high gain. The high-gain post picks up the grid of the first 6J7 and the low-gain post the grid of the second 6J7. The second volume control is a .5-meg. potentiometer in the grid circuit of the second tube.

The control grid of the first tube is biased about one volt by means of a Mallory bias cell. The second tube is self-biased by means of a 2,500-ohm resistor, shunted by a 20 mfd. condenser. The 6C5 signal divider tube is also self-biased, by a 3,000-ohm resistor, shunted with a 10 mfd. condenser. Finally the two power tubes are biased by a 200-ohm resistor in the common cathode lead, and this resistor is shunted by a 25 mfd. condenser. It is necessary to use a large bypass across the bias resistor, if any condenser at all is used, because the resistor is comparatively low. It is customary in P. A. work to include the condenser even in push-pull circuits where not otherwise needed, so that if one push-pull tube goes dead

(Continued on following page)

(*Continued on following page*)

the amplifier will not distort much and the program can go on.

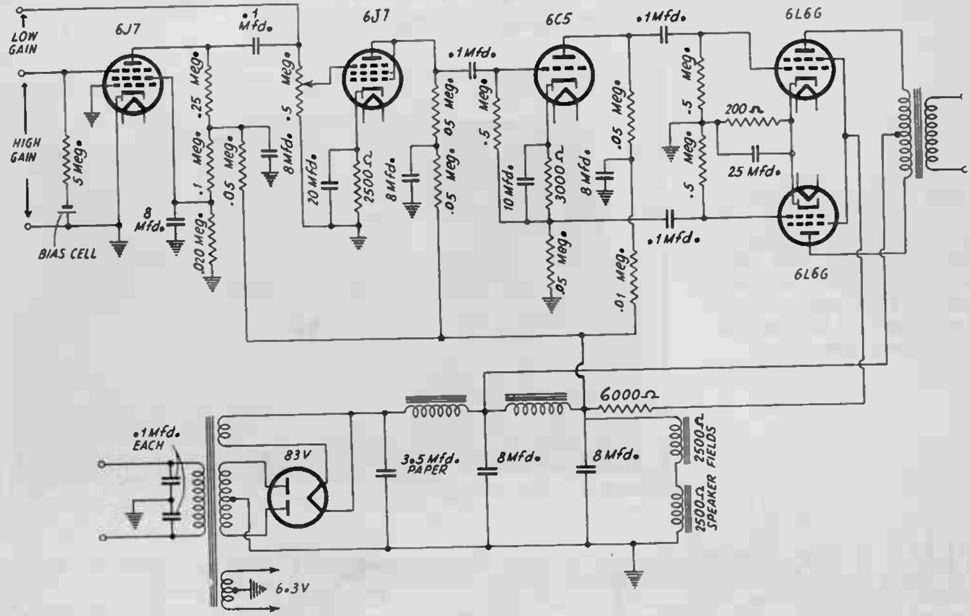
The large bypass capacity across the bias resistor for the second tube is required to eliminate stray coupling, since an amplifier as sensitive as this can easily break into oscillation.

AMPLIFIES TO 20 CYCLES

It should be noticed that bypassing is thorough. The reason of course, is that the amplifier is resistance-coupled and that low notes, as well as the high, are amplified strongly. This high-gain on the low notes is intentional, for the grid stopping condensers are large and the grid leaks in series with them are also large. Thus the time constant of each grid circuit is .05, which is high enough to allow almost full amplification on notes as low as 20 cycles per second. This precaution was carefully taken into account by Leo Speiser, my associate, who wired the amplifier.

Not only are the cathode circuits thoroughly bypassed, but also is the supply circuit. Thus there is an 8 mfd. condenser from the screen of the first tube to ground, and a similar condenser across the B supply. In the plate circuit of the second tube is another filter consisting of one 8 mfd. condenser and a .05 megohm resistor. This is repeated in the third plate circuit except that the resistance is .01 megohm. In addition to these individual filters there is a common one in the B supply. The stages are therefore well isolated from each other and there is a negligible stray coupling between them.

As a means of minimizing the chance that line noises will enter the amplifier by way of the power supply there is a filter in the primary of the power transformer, and this consists of two .1 mfd. condensers in series, with their junction grounded.



This is the complete circuit, with design constants, of the Harvey 137 high-quality, high-gain power amplifier. If only one speaker is used, one field can be replaced by a 2,500 ohm 25-watt resistor.

THE LAYOUT OF AMPLIFIER

The grid bias cell in the first stage is used as a means of minimizing hum and to eliminate motor-boating. The hum is reduced because the cell makes it possible to ground the cathode of the tube and the motor-boating is eliminated because the feedback through the bias resistor is prevented.

The arrangement of the parts in this amplifier is indicated in the photograph. At the extreme left are the two 6J7 tubes. Then comes the 6C5, and this is followed by the two 6L6G power tubes. Finally, at the extreme right corner, is the 83V rectifier tube. Some of the 8 mfd. bypass condensers can be seen back of the tubes, as can also the filter chokes and the power transformer. In front, on the panel, the volume control knob can be seen at left, the line switch in the middle, and the speaker outlet socket at right.

An amplifier of this kind is suitable for use wherever a large volume and first-rate quality are required. Specifically, it can be used with any radio-frequency tuner in which there is a detector, with a phonograph pickup unit, with a microphone, including crystal and ribbon types, with a photo-electric cell and serves well also as a speech amplifier to modulate a 30-watt transmitter 100% or a 50-watt transmitter 60 per cent.

The gain is 120 db. which accounts for the suitability of input from low-sensitivity (but high quality) microphone. If a carbon microphone is to be used, a matching transformer input would be necessary, and the connection of secondary would go to the low-gain input terminals.

LIST OF PARTS

Coils

One power transformer.
One push-pull output transformer (built into speaker).
Two filter chokes.

Condensers

Six 8 mfd. electrolytic condensers, 600 volts.
One 20 mfd. electrolytic condenser, low voltage.
One 10 mfd. electrolytic, low voltage condenser.
One 3.5 mfd. paper condenser, 600 volts or more.
Six .1 mfd. condensers.
One 25 mfd. electrolytic.

[All condensers products of Cornell-Dubilier]

Resistors

One .5 meg.
One .1 meg.
One 6,000 ohm.
One .5 meg. potentiometer
One .02 meg.
One 3,000 ohm.
Three .5 meg.
Five .05 meg.
One 2,500 ohm.
One .25 meg.
One .01 meg.
One 200 ohm.

[All resistors products of International Resistance Company.]

Other Requirements

One Mallory bias cell.
One four-contact socket.
One toggle switch.
Two grid clips.
Tubes: two 6J7's, one 6C5, two 6L6 G's, and one B3V.
Five octal sockets (Isolantite for 6L6 G's).
One speaker socket.
Three binding posts.
One chassis 14x9x3 inches.

[All tubes products of Hygrade-Sylvania.]

TWO GENERATORS AND A BRIDGE ARE AMONG EQUIPMENT USED IN MEASURING AND ALIGNING NATIONAL COMPANY NC-100 RECEIVERS.

A Direct-Reading Q Meter

Simple Solution of Knotty Problem

By Einar Andrews

$$I = \frac{E}{R} \qquad I_1^2 = I_2^2 = I^2/2 \qquad I_1 = I_2 = .707I$$

$$I_1^2 = \frac{E^2}{R^2 + \left(L\omega_1 - \frac{1}{C\omega_1}\right)^2} = \frac{I^2}{1 + Q^2\left(\frac{f_1}{f_0} - \frac{f_0}{f_1}\right)^2}$$

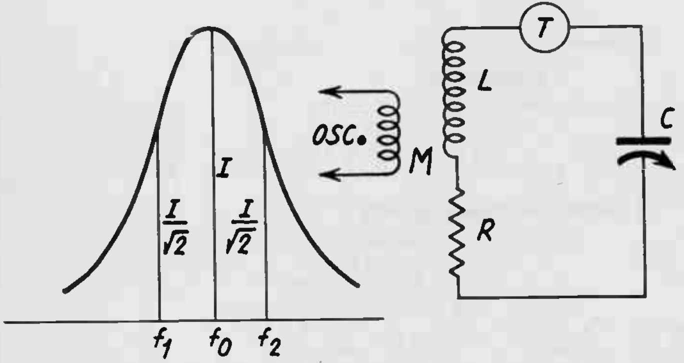


FIG. 1
This illustrates a method of measuring the selectivity, or Q, of a coil by means of a calibrated oscillator, a thermo-couple milliammeter, and a variable condenser.

THE usual method of measuring the selectivity, or the Q, of a coil is illustrated in Fig. 1. The coil L upon which the measurement is to be made is very loosely coupled to a strong oscillator of variable frequency by means of another coil L_1. The coil L is connected in series with a suitable thermo-milliammeter T and a variable condenser C. The frequency f_0 at which the measurement is to be made is supplied, and the circuit containing L is tuned to resonance by means of C. The intensity of oscillation, or the degree of coupling M, should now be increased so that the milliammeter reads full scale when the circuit is tuned sharply to f_0.

Condenser C and the power supply are left alone, except that the oscillator frequency is varied downward until the thermo-galvanometer reads one-half scale. The frequency f_1 at which this occurs is noted. Then the frequency of the oscillator is once more varied, upward and through resonance, until another point is found where the reading on the thermo-galvanometer is one half scale. The frequency f_2 at which this occurs is noted.

The Q of the coil L can then be computed from the formula

$$Q = \frac{f_0}{f_2 - f_1} \quad \text{..........................(1)}$$

This formula is derived as follows. When the current is .707 of the resonance value, or when the current squared is $I^2/2$, the tangent of the phase angle is either plus 45° or minus 45°. That is, the ratio of the reactance in the circuit to the resistance is equal to 1 or —1. In terms of Q and the frequencies the two ratios can be written

$$\left.\begin{aligned} Q\left(\frac{f_2}{f_0} - \frac{f_0}{f_2}\right) &= 1 \\ Q\left(\frac{f_1}{f_0} - \frac{f_0}{f_1}\right) &= -1 \end{aligned}\right\} \quad \text{............(2)}$$

Multiplying the upper equation by f_0f_2 and the lower by f_0f_1 and then subtracting the lower from the upper yields

$$Q(f_2^2 - f_1^2) = f_0(f_2 + f_1)$$

which reduces to (1) when divided by the coefficient of Q and reducing the expression to its lowest terms.

If the inductance of the coil is known, the resistance can be computed as soon as Q has been obtained. The appropriate formula is

$$R = \frac{2\pi f_0 L}{Q} \quad \text{..........................(3)}$$

To get the true resistance of the coil the resistance of the thermo-galvanometer must be subtracted from R as given by (3).

The method described requires some computation before Q is known. It is more convenient to have a direct-reading instrument. Referring to Fig. 2, let G be an oscillator of variable frequency and VTVM a vacuum tube voltmeter calibrated in volts. Let L_x be the coil under measurement, C a variable condenser, T a thermo-milliammeter, and R_0 a small non-inductive resistor.

The oscillator is started at the frequency at which the measurement is to be made and C is varied until the vacuum tube voltmeter shows maximum voltage across the condenser. That is, L_xC is tuned to resonance with the frequency supplied. The intensity of oscillation is varied until the thermo-milliammeter shows a suitable deflection. This is to be the same at all subsequent measurements.

Let E_1 be the effective sum voltage across the meter and R_0 and let E_2 be the effective voltage across the condenser C. Then we have

$$E_1 = RI_2$$

$$E_2 = I_2/C\omega \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

where R is the resistance in L_x and I_2 is the effective value of the current through the coil and the condenser. Dividing one equation by the other to eliminate I_2 yields

$$Q = E_2/E_1$$

since $Q = L\omega/R = 1/C\omega R$.

The vacuum tube voltmeter measures E_2 directly, E_1 may be kept at a multiple or submultiple value of 10 so that Q may be read from the voltage scale without computation. Just what E_1 should be depends on the sensitivity of the thermo-milliammeter and on the range of Q's to be measured. Suppose that the internal resistance of the milliammeter is 4.6 ohms. One convenient value for the external resistance R_0 is .4 ohm. The total resistance is then 5 ohms. Suppose, then, that the current is kept at 100 milliamperes. This means that the voltage E_1 is always adjusted to .5 volts, and Q is numerically equal to twice the indicated value of E_2. If the Q is 100, the VTVM will have to read 50 volts; if Q is 10, VTVM will read 5 volts.

To make the meter read directly the current through the milliammeter would have to be .2 ampere. If Q is to equal $10E_2$, the current would have to be .02 ampere, or 20 milliamperes.

It is clear that the method can be used with two VTVM, instead of with one VTVM and a thermo-milliammeter. One of the VTVM would then be connected across R_0, which would be of a suitable and a low value. Adjustments could be made so that $Q = .1E_2$, $Q = E_2$, and $Q = 10E_2$ by making suitable choices for E_1.

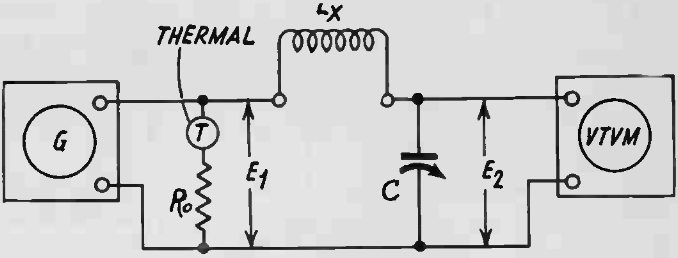


FIG. 2
The circuit of a direct-reading Q meter which utilizes one thermo-milliammeter and one vacuum tube voltmeter.

Two Variables Eliminated

The Q meter shown in Fig 2, which may be direct-reading by suitable choice of constants, as explained in the text, is based on a comparison of two voltages. The resistance across the generator must be low, hence T is a low-resistance thermal meter, and R_0 is small. The current therefore must be large. Always the current or voltage on this side must be the same, and a specified amount, preferably related to multiples or submultiples of 10.

The total voltage across TR_0 is impressed on the series circuit, where the inductance is Lx, the Q of which is to be measured, and the capacity is C. CL_x are tuned to generator resonance, maximum deflection on VTVM, and if the decimal series was considered, as suggested, the Q is directly read from the voltage calibration of VTVM.

The system works well because taking for measurement the voltage drop across C, where C is a high-grade condenser, the a.c. resistance is negligible, whereas in the coil the a.c. resistance is large. Because of the a.c. resistance across VTVM is negligible, that resistance may be eliminated from consideration, and becomes a rejected constant.

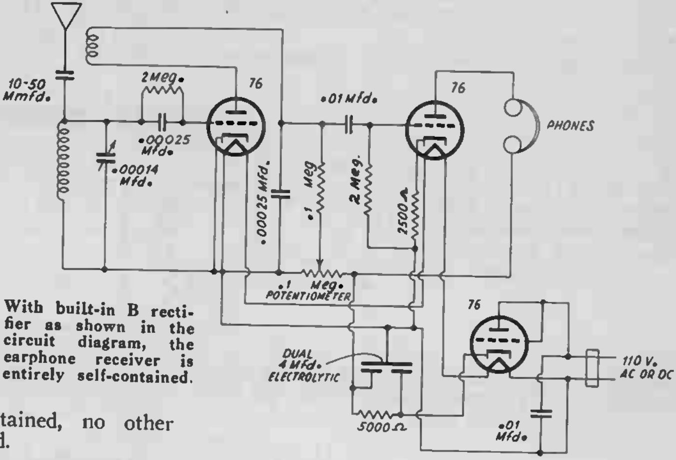
Since the current is held constant by adjustment to the same value, or E_1 is always the same, the a.c. resistance of the VTVM circuit is negligible, including loaded condition, two otherwise variable factors are eliminated, only a voltage remains to be considered, and that is proportionately greater the higher the Q. Hence Q may be read directly in terms of voltage, including decimally.

Regenerator Needs A.F. Stage

Assistance to Detector Exemplified

By J. L. Miles

Eilen Radio Laboratories



With built-in B rectifier as shown in the circuit diagram, the earphone receiver is entirely self-contained.

DESIGNED for the short-wave fan interested in the construction of a simple yet efficient receiver, this compact model uses a minimum of parts in a time-tried circuit. This model may be constructed for a few dollars and will give the same results as many five- and six-tube receivers.

The diagram shows that three type 76 tubes respectively as regenerative detector, stage of audio and B rectifier. The receiver is entirely self-contained, no other parts whatever being required.

GAIN HEIGHTENED BY A.F. STAGE

The main tuning control is mounted on the right-hand side of the cabinet. To the left of it is the regeneration control potentiometer. On the left end is located the plug-in coil and the headphone jack connections. All tubes are mounted on top of the cabinet.

The received signals are fed into the grid of the detector tube through the antenna series condenser C_1. Tuning is accomplished by means of the condenser C_2 and the coil L_1. Grid leak and grid condenser values of 2 meg. and .00025 mfd. respectively are used. The output of the detector tube is resistance-capacity coupled into the grid of the second 76 tube, audio amplifier. Bias for this tube is furnished by the resistor R_5. The headphones are connected in the plate circuit of this tube.

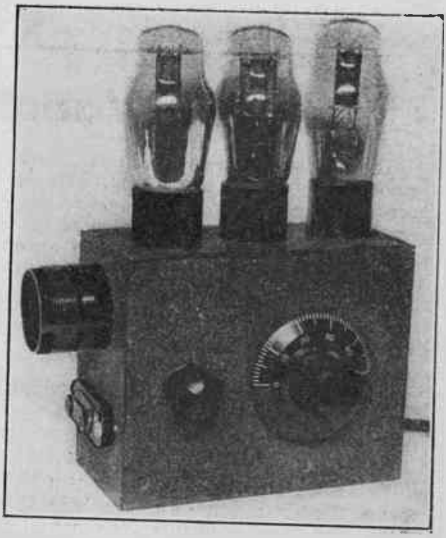
The 76 rectifier has a filter system C_5-R_6 that removes hum.

The heaters are connected in series and are fed from the house current, which is limited to the proper value by the resistance built into the line cord.

GOT EXCELLENT RESULTS

All parts and connections are made inside the cabinet, resulting in a simple and neat receiver Four coils are used to cover the short wave range of 10 to 200 meters. An additional coil enables reception of standard broadcast band station.

The author, using this receiver, has logged foreign as well as domestic short-wave stations. Amateurs, police calls, short- and long-wave broadcasting, code and experimental services were heard with volume and regularity.



The circuit is built on a chassis that fits into a compact box, with coils plugged in at the side.

Restoring Lost Pep

Realignment and Other Remedies Applied

By Conrad V. Mansfield

LOSS of pep is a frequent complaint from customers, the remedy for which is usually long delayed, because while a set plays at all there is likely to be insufficient incentive to call in a service man.

For a tuned radio frequency set the remedy is usually to realign the circuits by adjustment of the trimming condensers at or near the high-frequency end, and even a station may be used as guide to the ear. Or, if the coils are unshielded, they may have become defective through exposure, acquiring in other words very low Q, and when replaced would cure the ill.

But with the superheterodyne the case is somewhat different, because there are more circuits.

"The customer says the set doesn't play as loudly as before," one hears. "I checked up on the components and everything is O.K."

SUSPECT THE I.F. CHANNEL

What does this indicate? The i.f. coils are out of alignment. That is the first assumption, and realignment is made at once. This can not be safely done using a station as guide, because of several reasons. First, if the set is sensitive when operating properly, if the i.f. is realigned on the basis of a station, some other station, 10 kc this side of the one intended to be used, may be carrying the same chain program, and one may misalign, with one transformer 10 kc removed from another.

If there is automatic volume control the complications become serious, as the resonance point is masked. You can not tell accurately by listening just where to stop turning the setscrew, because there is hardly any change in the quantity of sound output. If there is a resonance-indicating device that works on the i.f., then there is a helpful guide. Not all receivers having a.v.c. are equipped with such an indicator, although they should be. Business in installing ray indicator tubes or tuning meters has sprung up for that reason.

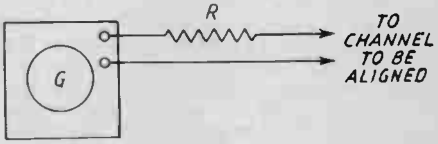
SIGNAL GENERATOR RECOMMENDED

The reason why the i.f. coils are suspected is that nearly all sets have compression type adjustments for the i.f. condensers (excepting the highest-grade receivers with air-dielectric condensers), and meteorological changes, as well as vibration, cause displacement of plates. Even if the displacement is equal there is harm, as the intermediate amplifier becomes tuned to a frequency different from the intermediate frequency put out by the modulator.

A signal generator should be used for lining up the i.f.'s. For a.v.c. sets the input should be weak, so that little, if any, a.v.c. voltage is developed. Where sets have delayed a.v.c., meaning that no a.v.c. takes place until a certain i.f. amplitude is developed, the signal generator should deliver less than the voltage that would start the a.v.c. working. In a tight case it might be advisable to short out the a.v.c., so that affirmative indication is obtainable, especially if one has to rely on the makeshift of aural response.

REDUCTION OF LOADING

One way of reducing input is to place a resistor in series with the generator output. This has the extra advantage of reducing greatly the load put upon the circuit by the generator. A resistor of 10,000 ohms or so will suffice usually. A very low impedance input connected across an i.f. circuit, or from control grid of local oscillator to ground, may practically short the intended input.



R is the series resistor.

With the local oscillator of a pentragrid converter tube thus paralleled by generator output, where generator has low impedance, the signal may come through fairly well, and if so will suffice, because this circuit is isolated from the i.f. channel. But if connection is made across any i.f. winding, generator having low-impedance output, the adjustment is rendered difficult because of the broadness introduced, as well as the great reduction of the generator's signal.

SWISH METHOD DESCRIBED

In many locations any stations that would be used for checking the i.f. would be so loud that a.v.c. always works, also without the generator the i.f. channel's actual frequency is not known and as the padding for tracking purposes in the tuner depends on the i.f., the whole arrangement ahead of the i.f. may be upset. Surely

(Continued on following page)

(Continued from preceding page)

there will be tie-down at two selected tuner points, but there may be great departure thereafter, with resultant squeals due to mistracking.

It is my preference to use a signal generator without modulation, or only the swish heard from the generator, augmented by that from the set. Finer adjustment is more readily made that way. Without a.v.c. complications, an excellent alignment job can be done by listening. If a meter is used it may well be in the second detector plate circuit, or, in the case of a diode, a 0-1 milliammeter in series with the continuous signal rectifier circuit. Really, a microammeter is more suitable, as there would be small deflection even on a 0-1 milliammeter for anything save a husky signal. But by close observation one may make a good job of the visual realignment with the 0-1 milliammeter.

Loose coupling to i.f. channel.

COIL PROBLEM SERIOUS

Now, if the intermediate channel is properly aligned there should be no tracking trouble, and won't be, if the tuning condenser is a good one, and the coils are proper. The r.f. coils set the pace. The premise is that these are always right. The oscillator has to track them by a difference constantly equal to the intermediate frequency. That is, for 600 kc tuner level, the r.f. is 600 kc, whereas the oscillator is higher by the amount of the intermediate frequency, or 600+i.f. For 456 kc the oscillator would match the r.f. when generating 600+456=1,056 kc. However, the absolute oscillator frequency is seldom measured directly. A computation is applied, where tracking prevails, or the numerical quantities ignored, the fact that there is tracking being all-sufficient.

A receiver that has a frequency-calibrated dial presents a problem, just as the oscillator tracking does, because the dial may be tied down at 600 kc whereas the true required frequency may be 610 kc for this setting. The circuit requirement is persuasive, the dial coincidence secondary. It is imperative to find the r.f. levels, and this may be done with bypassed earphones in the plate leg of the modulator, with local oscillator kept going, but care being taken to distinguish between any beat due to the local oscillator and a station, and response due to the r.f. level tuning alone.

SHARP DISTINCTION

Here again a signal generator comes in handy, as the distinction then is sharp, especially when the generator is modulated.

If the local oscillator is suspected of interfering the generator is detuned a bit, and the alignment made at this new frequency, instead of exactly at the standard one, say, 610 kc, or 1460 kc. Usually the two frequencies for the broadcast band are 600 kc and 1,450 kc, although quite a few late sets are recommended to be aligned at 1,500 kc, because they tune to higher station frequencies, even picking up amateurs after exhausting the broadcast band. It is well to pad by the parallel trimmers at the high test frequency and then adjust the series padder for the other end.

When the two points are noted, the dial is coincided with them, if possible. Sometimes this may be done by a slight movement of the dial, condenser kept stationary, by loosening the dial setscrew. Then see what happens at the other end. Since the r.f. level alone is concerned, no padding problem enters. As the dial now tracks or does not track the circuit, so should it track or not track later, because the padding of the local oscillator must be done in respect to the r.f. tuning, regardless of what the dial reads. This fact may be explained to customers as follows, even though they are not strong on technical talk:

'The dial turns a gang of tuning condensers, and one of these condensers must have a different capacity value from the others, to prevent squeals, and improve sensitivity and selectivity. If the dial reads frequencies not quite the same as those actually tuned in, that is a manufacturing matter, and can not be cured by servicing."

IS OSCILLATOR COIL RIGHT?

Seldom will customers complain much if the dial reads a bit off, as it is difficult at best for manufacturers to turn out sets with such precision as some customers might desire, without price increase.

When it was said "that is a manufacturing matter," the difficulty surrounding the oscillator coil is inductance was not out of mind. Service men today are not equipped to check whether the oscillator coil is right or wrong, and if wrong in what direction, and how to remedy the trouble.

Suspicion of oscillator inductance trouble usually results in the set being sent back to the factory, as the service man feels the job is too much for him. If there is no factory any more, why that is just too bad. However, a few pointers will be given.

1. The r.f. level alone is checked at five points, the two previously mentioned, or substitutes as recommended by the manufacturer, also at about the middle of the band, around 930 kc, and besides, the terminal frequencies are noted, say, 1,700 kc and 530 kc.

2. The frequency ratio equals the higher divided by the smaller terminal frequency, or 1,700/530 = 3.21, closely. Add the intermediate frequency, say, 456 kc, to both terminal

frequencies, and ascertain the frequency ratio required of the local oscillator's condenser. (1,700+456)/(530+456) = 2,156/986 = 2.187 closely. So no matter what the coil is in the oscillator, pad the oscillator so that the frequency at one end is 2.19 that at the other. The parallel trimmer setting was found previously. The series padder alone is adjusted. Beat the local oscillator and signal generator, listening in the local oscillator plate circuit with bypassed phones in series with plate, or, better, using a tube voltmeter or ray indicator tube or a grid dip meter.

3. The full receiver is now set going, and the midpoint of frequency test is selected, 930 kc approximately, the third point not usually considered. If the frequency to which the receiver responds when turned to this mid-position is higher than it should be the inductance of the local oscillator coil is too small. If the frequency is lower the inductance is too large. Turns are added to increase inductance, taken off to reduce it, a single turn being "a whole lot," unless the frequency disparity is great.

4. After the midpoint has been made to coincide with the frequency to which the set should respond as a super just as it did as a t.r.f. trial, the padding and trimming of the local oscillator may be redone at the two test frequencies, say, 600 and 1,450 kc.

COIL ENGINEER, TOO

The method just outlined is not perfect, as the tracking does not depend only on ratios but also on definite absolute values to attain the ratios, and these absolute values are not known or ascertainable, unless one knows which of the three tracking methods was intended by the set designer. Such information a service man never has. However, there was a serious fault, and there has been a serious improvement, and excellent progress has been made in tackling a problem any service man will admit is tough, of getting the local oscillator inductance right. Pep loss has been reduced, squeals eliminated, too.

"Am I supposed to be a coil engineer, too?" the service man may ask himself. And apparently the answer is, or will be, "Yes."

FORUM

SEQUENCE DELIGHTS H. N. BLISS

I compliment you on your magazine, which I have read without missing a copy since th first Diamond of the Air appeared.

The advantage of being able to start one o your articles and finish it on the succeeding pages, instead of being shot back to a lot o fine print mixed up with the advertising, i worth a lot. Please don't ever change tha policy.

H. N. Bliss
107 Elmwood Avenue, Ithaca, N. Y

* * *

NEWCOMER WELL SATISFIED

I have been buying your excellent magazin since February and have found it most worth while.

Edwin A. Wolf,
Wolf Radio Service Laboratory,
115 Church Street, Roxbury, Mass

* * *

OUR FACE GETS REDDER

I send my compliments to Radio World. I is a very complete magazine. Best wishes fo its continued success.

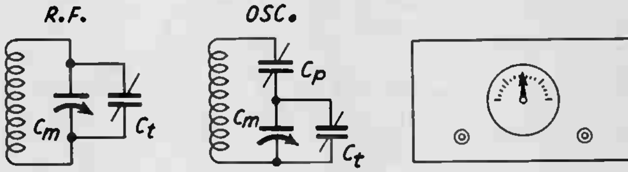
Robert Wray
P. O. Box 84, Red Bank, N. J

* * *

"GREAT HELP" IN SERVICING

I find Radio World a great help to me in m work as a service man.

Bert Stone,
1 Corrigan St.
Kingston, Ontario, Canad



Representation of r.f., oscillator and the mid-dial position of a set for test.

THE JANUARY ISSUE will contain a constructional article on an inexpensive cathode-ray oscillograph, using the new 913 (see page 46). Also a multi-purpose tester based on a signal generator foundation, will be described. Both articles will be important and distinctive.

Service Price Proprieties

Substantial Minimum Rate is Favored

By Jack Goldstein

PARTICULARLY in the large centers of population, where service competition is severe, and various devices are used to attract business, disgraceful evils have sprung up, and the public is the victim, as usual. Individual service men and large organizations as well are participants in this victimizing, which consists, frankly speaking, of dishonest practice. Mainly charges are made for parts that are not replaced at all, and good parts are removed from receivers being serviced, poor ones or used ones substituted surreptitiously, tubes being switched quite often as a regular business practice.

No one openly or covertly defends these practices, except perhaps those engaging in them, but nearly all the evils derive from the bitter competition present in these fields. To get business, offers of a most unbusinesslike nature are made, sometimes a fixed low price, like 50 cents, for an inspection call, and since the charge does not even cover the cost of the trip, some way must be found for making the business at least self-supporting, if not profitable.

MUST MAKE UP THE LOSS

So the very nature of the problem dictates the requirement of a fair charge for service rendered, and ordinary honesty should prompt one to charge for parts only if those parts are actually supplied.

A 50c charge, as made by some concerns, among them reputable ones, is against good business practice, because in some other way the loss has to be made up, and the temptation is to charge exorbitantly for such parts and service actually rendered, so there is no bargain for the customer at all.

The 50c charge is for inspection of the set, and as a matter of practice some very insignificant service work may be included, such as tightening a setscrew on a volume control, or pushing a pointer back that was scraping on a dial disc. The service man then tells the customer what is the matter with the set, and how much it will cost to have it fixed. It is a guess, or stock "diplomatic" diagnosis, and is almost always far from the truth.

Now, on this point I do not want to be over-severe, because many customers just naturally want to know what is wrong with a receiver.

CAR IS A NECESSITY

The fact is of course that the service man, whether he is an independent, honest or not, or works for a large organization, honest or not, very likely does not and can not know what is the matter with the receiver, for that nearly always requires a test much more exhaustive that any he will give on the customer's premises, or that his time allotment will permit. You see, he can afford to spend only so little time on each 50c call, in fact, at 50c, can not afford to spend even a few seconds, as the anticipated payment is used up in transportation and time back and forth.

This is true because in the large centers, no less than in the small ones, the service man must have a car, and the full cost of amortization and upkeep of the car must be charged against the business in which it is used. So the fact that a 50c charge for a perfunctory visit is a mask is obvious, and labor, most precious of assets, is used as a "loss leader."

I myself am engaged in the service business and I know the full necessity of making the business pay. It is of no purpose to state the idealism of the man who is a failure at servicing because he is too soft to get business. It is admittedly a hard task to get the repair jobs, a hard task to do them well, and a hard task to satisfy the customer, and get paid the fair value of the service, even when the work has been done expertly and the charges are literal and honest. And even after the work has been done at small pay, the customer asks:

"Will you guarantee the set for six months?"

WHAT ABOUT GUARANTEE?

The sensible answer to an idealist would be no, but the answer must be some sort of yes, for yes is the answer that the customer wants. It is beyond all reason.

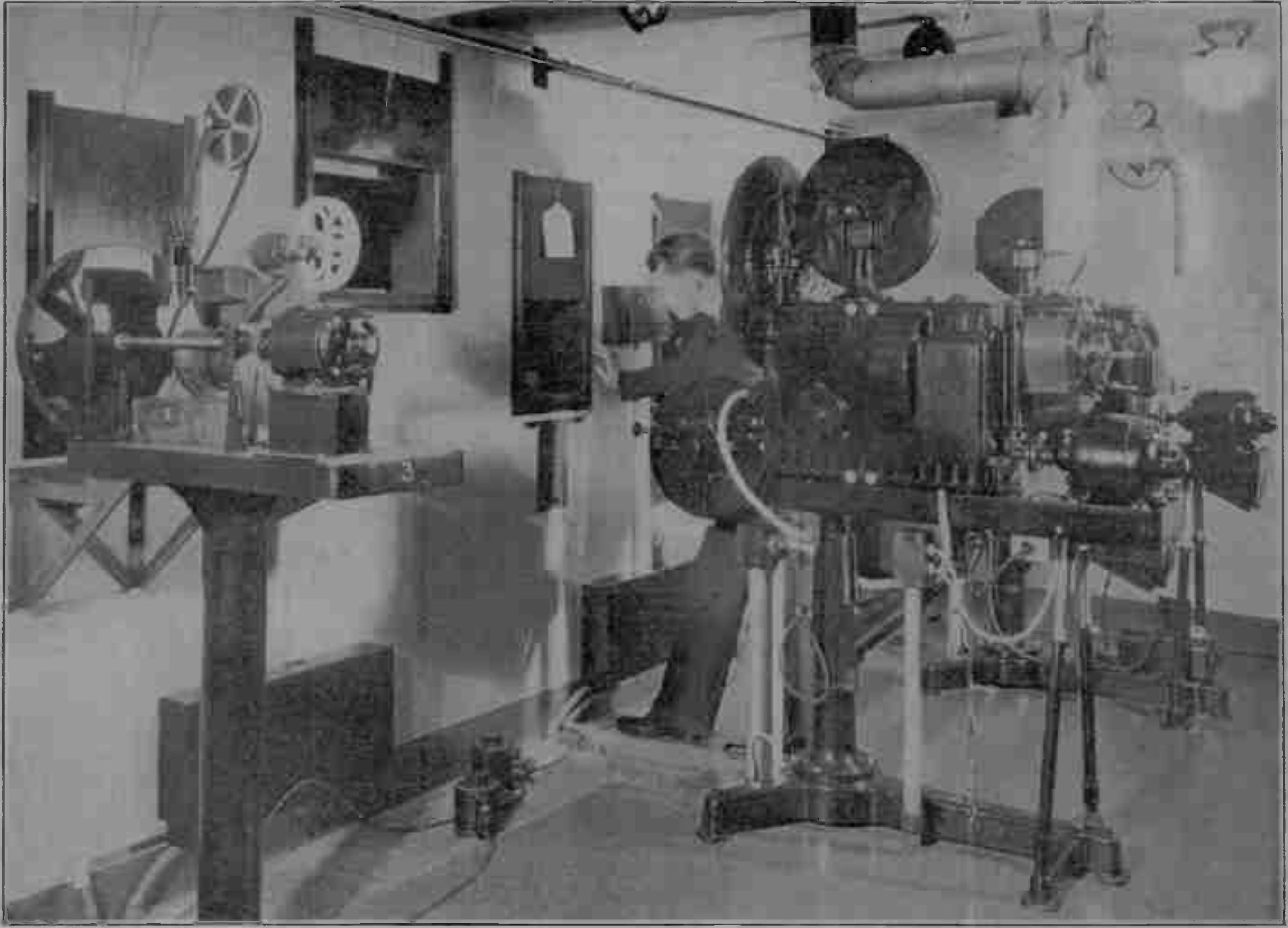
First, the customer, who knows nothing about radio, wants to know what is the matter with the set.

Second, the customer wants a guarantee. And a guarantee of what? The parts and the labor performed by the service man? No, not just that, but a guarantee of the entire receiver—that it will play satisfactorily for six months after the servicing job has been done!

What does that require that the service man do? It requires that he guarantee the tubes, which he neither made nor sold; guarantee the parts, which the set manufacturer put in, and which that manufacturer himself does not make, and perhaps even now, due to expiration of the standard 90-day guarantee, does not stand behind; also that the service man guarantee against damage that pests may incur on sets; in a word, guarantee everything, most particularly things with which he had nothing to do!

It is needless to argue that the customer is

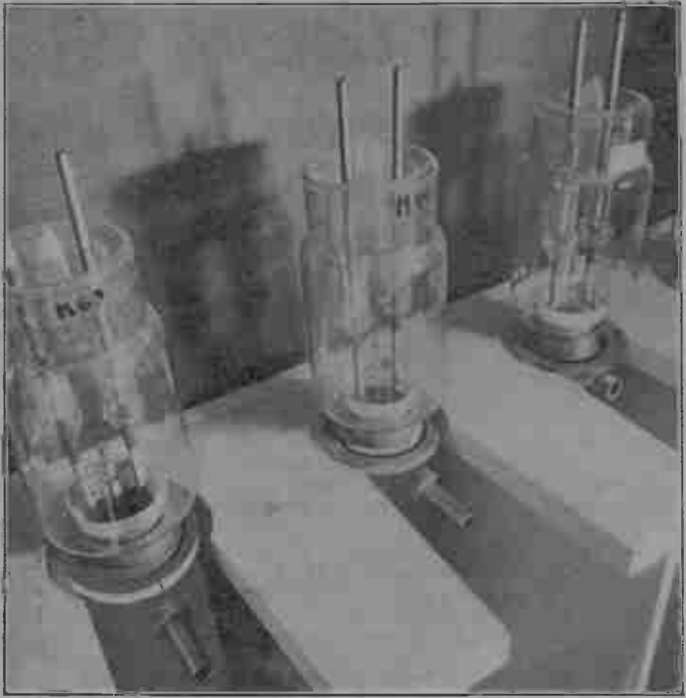
Notable Television Advance Demonstrated; Field Problems Yielding to RCA Science



Motion picture film is placed in the projection machine (right) and run off exactly as in any motion picture theatre. Instead of projection in large size on a screen, the image is focused on an Iconoscope, or television camera. The optical picture is transformed into electrical impulses, with which the r.f. carrier is modulated. Besides film, live pickup is used, as in studio illustration on the front cover.

Observer Reports on Results

Leon L. Litt, attending the demonstration at the National Broadcasting Company of the RCA high-defintion television, as observer for RADIO WORLD, reports that the 45-minute program was perfectly staged. Light green and "peasoup" green pictures were shown, he says, and the demonstration was given in darkness. The 343-line picture, 30 frames, interlaced scanning, he found, provided fairly good definition.



High-frequency transmitting tubes, used in RCA's television transmitting station in the Empire State Building. These are video-frequency amplifiers.

Four New Features Mark Impressive Television Showing

TELEVISION program transmission was demonstrated recently by the National Broadcasting Company in a 40-minute program illustrating RCA experimental developments. The pictures were broadcast from the transmitter on top of the Empire State Building and were received on the 62nd floor of the RCA Building.

The demonstration possessed four features not included in previous demonstrations of television.

1. IT was the first made by RCA and the National Broadcasting Company for the press under practical working conditions, although previous demonstrations of laboratory television had been given.

2. IT represented the first showing of a complete program built for entertainment value as well as a demonstration of transmission.

3. IT also included the first showing of a new 12-inch receiving tube, which reproduces a picture on a 7½ by 10 inch screen. This is the largest screen yet employed which is capable of commercial adaptation.

4. A television tour was conducted behind the scenes. By means of an especially prepared moving picture film, the guests were conducted through the NBC television studios in the RCA Building and the transmitter station at the top of the Empire State Building.

The watchers in front of the line of receivers installed for the demonstration saw the processes whereby performances by "live" talent are transformed into pictures through the air, witnessed the scanning of moving picture films, and observed in detail the intricate television apparatus in actual operation.

The guests saw studios adapted to television technique, the installation of equipment in those studios and at the transmitter atop the Empire State Building, the determination of workable engineering methods for the transmission of pictures, and the training of a staff to take over the operation of the plant.

[Illustrations on front cover and pp. 34 and 35.]

Sarnoff Tells of Expansion; 'Firmly Believes' Problems Soluble

By David Sarnoff

President, Radio Corporation of America

Our field tests in television began only on June 29 of this year. That date marked the beginning in this country of organized television experiments between a regular transmitting station and a number of homes. Since then we have advanced and are continuing to advance simultaneously along the three broad fronts of television development—research which must point the road to effective transmission and reception; technical progress which must translate into practical sets for the home the achievements of our laboratories; and field tests to determine the needs and possibilities of a public service that will ultimately enable us to see as well as to hear programs through the air. On all these fronts our work has made definite progress and has brought us nearer the desired goal.

We have been transmitting from our television station on top of the Empire State Building in New York City which is controlled from the NBC television studios in the RCA Building. We have observed and measured these transmissions through a number of experimental receivers located in the metropolitan area and adjacent suburbs. The results thus far have been encouraging and instructive. As we anticipated, many needs that must be met by a commercial service have been made clear by these tests.

LEARNED A GREAT DEAL

We have successfully transmitted through the air, motion pictures as well as talent before the televisor. The distance over which these television programs have been received has exceeded our immediate expectations. In one favorable location, due to the extreme height of our transmitter, we have consistently received transmissions as far as 45 miles from the Empire State Building.

The tests have been very instructive in that we have learned a great deal more about the behavior of ultra-short waves and how to handle them. We know more about interferences, most of which are man-made and susceptible of elimination. We have surmounted the difficulties of making apparatus function outside of the laboratory. We have confirmed the soundness of the technical fundamentals of our sys-

---

unreasonable. One can not forget that the service business as a whole has done much to make the customer unreasonable. One of the worst effects of the nominal service call charge is that it belittles the value of everything any and every service man does.

The impression sought to be made by the unfair competitor is that the low charge, or utter absence of charge, covers quite a considerable service, including actual repairing, i.e., labor. Actually, of course, the literal words are not used, because quick trouble with the authorities would be the result.

ADEQUATE MINIMUM CHARGE

But the customer gets the idea there is a vast profit in 50c calls and that anybody who charges more is dishonest, whereas anyone who fails to make an adequate minimum charge spends more time thinking up ways of making up for his losing trips than he does on servicing sets, until false statements become a routine.

One of the pet excuses is to say that a filter condenser is burned out. If this is said just to appease a customer who insists that he must know what is wrong, and the service man feels he must give some sort of answer, perhaps there is some justification, if later on he will admit, on returning the set, is was not the filter condenser, as he supposed, but something else, and he charges only for the real services he rendered, and the actual parts, if any, he installed. And he should not hesitate—in fact should make a business of listing the very parts that were put in, and might even show these parts to the customer.

Some persons get unduly excited over charges of a few dollars when only a pilot lamp is burned out, yet the service man has to make the visit, probably pull out the set, and perhaps devote an hour or more to the job. If he is conscientious he makes a point-to-point test, checks tubes, and renders other service, including a four-hour running test of the receiver, to be doubly sure everything was all right after the repair was made. Besides, he has to fix some sets at prices less than those justified by the long time spent finding the fault.

SUGGESTS $3 MINIMUM

My point is that it is the best business practice to adopt a minimum charge and to stick to that. It should be $3. In other words, nothing can be wrong with a set that isn't worth $3 of a service man's time to fix. He has only so many calls, he must average so much on the total of calls made, and he just about makes a living on a $3 minimum basis, therefore should not accept less.

Also, he will have to give the guarantee, as one of the evils he must suffer at least until the business is rationalized—the broad guarantee forced upon him unjustly—but this is his remaining weapon against oppressive dishonest competitors. If he will print his guarantee on his bill, make it sweeping, but limit it to three months, he will be able nearly every time to avoid assenting to six-months, because people seem to have deeper respect for what they see in print, though it is someone else's thought, than they have for spoken ideas, though these be their own.

BENEFIT TO PUBLIC

Moreover, it is absolutely bad business to do any work in a customer's home, even to soldering a disconnected voice coil lead in a speaker. Nobody's home is, or should be a workshop. The service man has his place of business and should perform his actual repair work there. Only there can he make the proper diagnosis, except for the unusually easy troubles. What service man carries into the home the full equipment he possesses? A tube checker is all he should carry. Even his analyzer should be left in the shop, where it belongs.

The public benefits from the fair minimum charge method of doing business, for the man who has enough realism and honesty to operate on that basis practically never runs into a service job for which he has to charge more than $8. Only in the examples of extraordinarily large sets, or where special work must be done to meet requirements of some console the customer likes, will the charge exceed $8. So as a rule one could say that a charge of more than $8 is exorbitant, and the exceptions are indeed few.

PAYMENTS OFTEN BEGRUDGED

Repair of a radio set is one thing a person does not like to spend money on, and service men may as well recognize that what they get is handed to them begrudgingly, and what work they do may not win the recognition it deserves, but the disgust with which a customer usually winds up his relations with a dishonest service man or organization means that the customer will turn elsewhere the next time, and in due course the reputable way of doing business will pay out.

EAR PASSABLE FOR ZERO BEAT

While it is not the highest form of accuracy to trust to the ear for zero beat, the practice serves a purpose, since it permits an adjustment otherwise not present or practical, and does improve the accuracy, compared to complete neglect of the precaution.

To calibrate a dial itself, use a protractor on a large board, draw a circle four times the intended dial scale size, and mark in the bars for the frequencies of the band from a curve sheet. Then photograph the drawing down to dial size and insert the print in place of the present scale.

REGENERATION IS OSCILLATION

Some contend that regeneration is nothing but oscillation. They are quite right because if there is to be any regeneration the circuit must be in a condition to oscillate. However, the oscillation must be feeble, so that the signal voltage can control the operation.

tem, and the experience gained through these tests enables us to chart the needs of a practical television service.

We shall now proceed to expand our field test in a number of ways. First, we shall increase the number of observation points in the service area. Next we shall raise the standards of transmission.

WILL CHANGE TO 441 LINES

In our present field tests we are using 343-line definition. Radio Corporation of America and the radio industry have, through the Radio Manufacturers Association, recommended to the Federal Communications Commission the adoption of 441-line definition as a standard for commercial operation. Our New York transmitter will be rearranged to conform to the recommended standards. That also means building synchronized receivers to conform to the new standards of the transmitter.

Synchronization of transmitting and receiving equipment is a requirement of television that imposes responsibilities upon those who would furnish a satisfactory product and render a useful service to the public. On the one hand, standards cannot be frozen prematurely or progress would be prevented, while on the other hand, frequently changing standards means rapid obsolescence of television equipment.

Basic research is a continuing process in our laboratories not only that the problems of television may be solved but also to develop other uses of the ultra short and micro waves which possess such vast potentialities in this new domain of the ether.

CLOSE ATTENTION TO PROGRAMS

While we have thus proceeded on the technical front of television, the construction and operation of television studios have enabled us to coordinate our technical advance with the program technique that a service to the home will ultimately require.

One of the major problems in television is that of network syndication. Our present facilities for distribution of sound broadcasting cover the vast area of the United States and serve its 128,000,000 people. Similar coverage for television programs, in the present state of the television art, would require a multiplicity of transmitters and network interconnection by wire or radio facilities still to be developed.

Our program is three fold: first we must develop suitable commercial equipment for television and reception; second, we must develop a program service suitable for network syndication; third, we must also develop a sound economic base to support a television service.

UNITED STATES LEADS

From the standpoint of research, laboratory development, and technical demonstration, television progress in the United States continues to give us an unquestioned position of leadership in the development of the art. In whatever form such progress may be evident in other countries, we lead in the research which is daily extending the radio horizon, and in technical developments that have made possible a transmitting and receiving system that meets the highest standards thus far obtainable in field demonstration.

We are now engaged in the development of studio and program techniques that will touch upon every possibility within the growing progress of the art. The distinction between television in this country and abroad is the distinction between experimental public services undertaken under government subsidy in countries of vastly smaller extent, and the progressive stages of commercial development undertaken by the free initiative, enterprise and capital of those who have pioneered the art in the United States.

The RCA experimental television receiver, which uses the Kinescope, or reassembler of optical images. The picture is viewed in the opening inside the hinged cover of the console. Both sight and sound are reproduced. Part of speaker grille is seen at bottom.

While the problems of television are formidable, I firmly believe they will be solved. With the establishment of a television service to the public which will supplement and not supplant the present service of broadcasting, a new industry and new opportunities will have been created.

P. A. Offers Real Profits

How to Get Started and Conduct Business

By M. N. Beitman

DURING the last few years public address has found such widespread application and public demand that those in the radio profession who took advantage of the possibilities in this new field reaped profits. But even now, years after the first application of sound amplification was realized, new uses for public address was found.

The sale and rental of public address amplifying equipment today offers the aggressive radio serviceman and experimenter opportunities to cash in on this growing market with little investment. It is quite common to hear servicemen say that they have received as much as $25 for a single evening rental of a sound system that actually represents a total investment of $60.

Anyone having a fair understanding of radio can swing into P. A. with very little additional study.

ENABLES CROWDS TO HEAR

The greatest application of sound amplification is to enable a large group of persons to hear a program. At mass meetings, church gatherings, theatres and concerts this application has filled a definite requirement. Instead of forcing the speaker to shout at his audience, thereby causing listeners in front to hear sound at uncomfortable volume levels and the ones in the rear to strain their auditory senses in trying to catch the words, public address amplification with properly arranged speakers enables all to hear the program distinctly and at a comfortable volume level. The speaker, by using a lapel type microphone, may move about, use his hands at will, and not be hampered in any way.

For reproducing a speaker's voice or for musical selections a microphone is used to change the acoustical energy of the sound to the corresponding electrical waves. Radio programs and phonograph records also serve as a means of input.

In amplifier design it is possible to incorporate controls, so that recorded music may be mixed and blended in any desired proportion with speech reproduced by means of the microphone. In talking-picture sound reproduction a photocell serves as the means of input. Amplifiers used in connection with photocell inputs usually have provisions for polarizing voltage and also furnish exciter lamp current.

SELECTION OF MICROPHONE

Essentially a P. A. system consists of one or more sources of inputs mentioned above, the amplifier or any pre-amplifiers necessary, and the output in the form of one or more loudspeakers so placed as to take the greatest advantage of the acoustics.

The size of the amplifier depends directly on the area of the service, and the noise level present. The size is also related somewhat to the reverberation time of the hall or other location of the installation. In halls where sound dies down quickly more audio power would be needed than under similar conditions in a hall where, because of acoustical conditions, the sound would persist for a longer period of time.

The type of microphone employed will depend on a number of factors such as funds available, type of amplifier used, quality needed, presence of feedback, etc.

A microphone is an efficient machine for transforming the sound waves into corresponding electrical energy. At the present time in P. A. practice the double-button carbon, crystal and velocity microphones are commonly used. Each of these microphones operates on a slightly different principle and has certain definite advantages.

CONTROLS USED IN P. A.

Amplifier units range in size from about 5 watts to about 60 watts. Although many much larger amplifiers are used, for all ordinary installations these sizes will suffice.

A quick examination of a commercial 8-watt amplifier will reveal that it is designed to be used with a low level crystal microphone and has very high gain. A tone control is included so that either treble or bass can be accentuated at will. Provisions are incorporated for a high impedance phonograph pickup. The microphone and phono inputs may be mixed and blended. Speaker and microphone connections are made to handy sockets. The speaker is of the dynamic type and its field serves an additional choke. Connections are also provided for an extra magnetic speaker.

In line with the demand for high quality this unit has an essentially flat frequency response from 45 to 10,000 cycles. In one particular unit metal tubes are employed. The unit is built on a crackle finished chassis with the power transformer, condensers, and tubes mounted above board.

A 35-watt powerful amplifier is completely encased in an attractive metal cabinet. The control panel forming one wall of the case has the mixing controls, tone control, switch, and red bull's eye indicator.

EXTENSION OF MIXING

All connections are made to sockets in the back. Inputs are provided for two-level microphones such as velocity or crystal types. There is also an input connection for a phonograph pickup, and it is possible to mix all three inputs. The output is available in 4, 8, 16, and 500 ohm impedances so that almost any speaker combination required may be employed. Excitation for two 4,000-ohm fields may be obtained. The new type 6L6 beam power tubes are employed in this unit's output stage.

Usually for indoor installations large-size dynamic speakers are selected. The usual 12-inch size can safely handle about 10 watts and the number of speakers employed in any one placement depends on the output capabilities of the amplifier and the type of location. The greater the coverage, the more speakers will be needed. For extremely wide coverage, and where sound must be distributed to many rooms, smaller permanent magnet speakers may be used.

For outdoor installations, or where sound must be directed, specially-designed baffles and trumpets are used. These are available in waterproof types for continuous use outdoors. Speakers may be also mounted in handy carrying cases for easy portability.

FEEDBACK PROBLEM

Poor placement of the loudspeakers in relation to the microphone will result in much undesirable feedback. If some of the sound from the loudspeakers reaches the microphone, either through direct radiation or from reflection from walls, and approaches in intensity the original sound, an echo will be noticed. A further increase in the intensity of the returned sound will result in a number of oscillations. Either of these two faults is objectionable and should be remedied.

If the speakers are made directional away from the microphone, the direct feedback may be eliminated. However, many times the acoustics of the place in question are such as to necessitate some major alteration in order to solve the feedback difficulty. Sometimes carpets are installed, and at other times it may be necessary to cover some walls or the ceiling with sound-absorbing material.

A more directional type microphone may solve the problem. Reduction of the gain in the amplifier will, of course, stop the feedback, but this action may occur at a volume level too low to enable the amplifier to be of much use.

The number of speakers selected for the particular use and the respective placing must be such as to make the program sound natural. It certainly would not do to have the loudspeaker in the back part of a long narrow hall. In such a case the listeners in the rear part would hear the natural voice of the speaker and the amplified equivalent at a considerable period of time apart.

PRACTICE SPEAKER ECONOMY

It is by far the best procedure to use as few loudspeakers as possible. Usually one or two prove entirely satisfactory. The loudspeakers should be so placed that the sound from them all and the voice of the person on the stage should reach the large majority of the audience almost at the same time. Of course, this will necessitate the condition that the loudspeakers should be about the same distance from the center of the audience as the orator.

In theatre work usually two speakers are employed and are placed above and a little to the right and left of the stage. A number of heavy curtains is drawn close behind the microphone on the stage. The speakers are made slightly directional forward to reduce possibilities of feedback. Carpets in the aisles and sound absorbing material on the back wall will also help.

LOW NOTES REQUIRE LARGE BAFFLE

Unless the speaker used is of the directional baffle or horn type a separate baffle will be needed. Otherwise the wave set up from the back of the cone will interfere with the wave set up in front, with the result that little or no sound will get out. The baffle increases the air path between the front and back. To be satisfactory for the lower notes a very large baffle board is needed, but one of about 40 inches square will serve.

The P. A. business resolves itself into two phases: rental and sales. Usually it will be found best to carry on business in both phases. In either case, however, the consumer must be found and correctly approached.

The average user will ultimately prove to be a buyer of sound equipment. At first the user of sound equipment may prefer to rent because he may want a trial under actual conditions, or he may lack funds for the purchase, or he has only occasional use for sound amplification. Most prospects approached, therefore, will find some early or later occasion to buy or rent. In case of rental an operator must usually be furnished to operate the system. Rental also necessitates temporary and improvised setup. A permanent installation, on the other hand, is properly placed and the owner or some other individual is instructed in the control operation of the system.

PERSONAL CALL RECOMMENDED

The users of public address equipment lie in almost all fields of human endeavor. Club houses, churches, stores, schools, parks, advertising cars are large users of sound equipment. Coal yards use small systems to speed up the weighing of trucks. Movies need hard-of-hearing sound equipment. Factories need call systems to locate employees quickly and with the minimum of effort. And you yourself probably have in mind a dozen more excellent applications of sound systems.

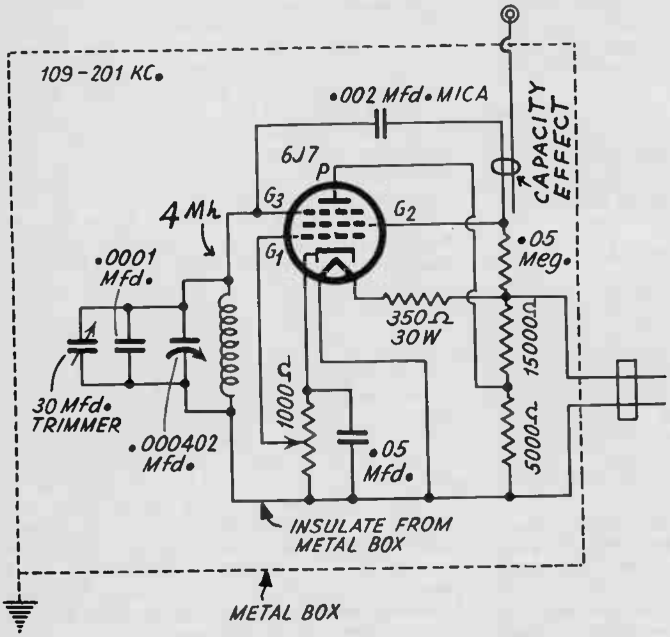
The best possible contact can be made by means of a personal call. At every rental the operator will be asked many questions. Usually many of the curious individuals will prove excellent prospects and should be followed up. When calling on any prospect have a small sample system along. By quickly setting up this system, you will be able to give your prospect a real idea what he may expect from a sound system.

Public address is the new money field; now is the time to get into it.

Accuracy Reaches .05 Per Cent

By Zero-Beat Calibration Method

By Henry Burr



A signal generator based on a positive mu oscillator, the latest thing in oscillators, a 6J7 metal tube, or 6J7G or 6C6 glass tube may be used. G1, overhead cap, is used for amplitude control only, hence attenuation may be applied, despite a.c. on the plate. G3, the suppressor, is the tuned circuit; G2 the screen, coupled to it by .002 mfd., producing oscillation because G2 and G3 are in phase. The .05 meg. load resistor is high enough for fundamentals to 1,000 kc. For higher fundamentals use .5 meg.

AN a.c. operated signal generator, using the line current without rectification, is practical on the basis of the diagram herewith. The tube may be a 6C6, 77 or 6J7. An unusual feature is that considerable attenuation is practical. This advantage is usually absent from strictly a.c.-on-plate generators.

The diagram shows a tuning condenser of .000402 mfd. Across this is a .0001 mfd. mica fixed condenser, and in addition a 30 mmfd. or larger trimmer.

SMALL, ACCURATE DEVICE

The object of the total parallel capacity is to make the tuning practically straight frequency line, that is, avoid crowding. With an inductance of 4 millihenries, as shown in the diagram, a single-winding coil, by the way, the lowest frequency is about 107 kc, due to total capacity of 550 mmfd., including circuit capacity, and the highest frequency about 205 kc, so that no frequency on the range is twice or half that of any other. The ratio therefore is purposely made a bit less than 2 to 1 to avoid possibility of confusion from an harmonic when intending to use fundamentals.

A commercial dial exists that has frequencies imprinted, 109 to 201 kc, taking up a little less than the full 180 degrees, to permit of a little adjustment of the dial either way. This sometimes improves the accuracy, which can be .5 per cent. without difficulty.

The device can be built into a small box, using a 4⅞-inch square panel on which are the attenuator, escutcheon and line switch.

It has been stated the fundamental frequencies imprinted on the scale are 109 to 201 kc. Since the primary object is to enable alignment of intermediate frequency levels at very small expense, 175 kc may be read directly on the frequency-calibrated scale, and also other intermediate frequencies in the range, using fundamentals.

The intermediate frequencies found on all-wave sets, however, are more than twice as great as the highest frequency of this single range, therefore the question arises, How are the higher frequencies to be measured, say,

LIST OF PARTS

Coil

One 4 millihenry universal-wound coil

Condensers

One special .000402 mfd. tuning condenser

One .0001 mfd. Cornell-Dubilier mica fixed condenser

One trimmer condenser, 30 mmfd. or more

One .002 mfd. Cornell-Dubilier mica fixed condenser

One .05 mfd. Cornell-Dubilier cub condenser

Condenser produced by two wires non-conductively related (see diagram)

Resistors

One 350-ohm. live cord and plug

One 5,000-ohm. One 15,000-ohm. One 50,000-ohm.

One 1,000-ohm. wire-wound potentiometer

Other Requirements

One metal box (use spacers to insulate this from line)

One escutcheon. Two knobs. Two binding posts (one to be insulated).

One miniature grid cap. One 6J7-tube (try several; not all oscillate)

One frequency-calibrated dial

One bracket for socket. One octal socket (connect shell to cathode).

400, 450 and 465 kc and 480 kc? These, too, are imprinted on the scale, and are used without possibility of confusion, because i.f. transformers intended for any one of these frequencies can not be set at any frequency that also would produce an unwanted and mystifying harmonic response.

HUSKY RESPONSE

The method used numerically was to select the intermediate frequency desired, divide it by 2 or 3, and read the fundamental frequency on the top tier equal to this. Hence the dividend frequency is the fundamental. If 480 kc is taken as the example, division by 3 yields 160 kc, so use 160 kc fundamental, mark it 480 kc on lower tier, feed the output of the generator either to the intermediate channel or to the control grid of a pentagrid converter tube, if one is used, and align for maximum response. There is constant modulation, due to the line frequency, and the note is husky. If the receiver has a.v.c., use the attenuator at lowest setting that produces an audible or visible response.

However, no such calculation is necessary for the stated intermediate frequencies, because these are on the dial, not once but twice. They are on twice as a double check of accuracy, in that there can be no confusion due to harmonics, for the i.f. is as stated, if the response is heard first at one generator setting and again at the other generator setting, nothing between. First align at one setting, then change the setting to the next one reading the same frequency, and the response will come in again.

FREQUENCIES TO 20 Mc

There can not be any mistake, because different harmonic orders of different fundamentals, both consecutive, are used. All the important i.f. are thus imprinted, save one, 456 kc, which is obtained by using 456/2=152 kc, and 456/3 =114kc. One alone may be used, but the other serves as a check, though, as stated, no error is possible.

The reason for taking up the numerical considerations, despite the lack of necessity of any computation, since the dial is direct-reading for the fundamental range and the important intermediate frequencies, is that higher harmonic orders permit measurement of still higher frequencies. Not only may these be extended readily into the standard broadcast band, but they may go still higher. With a good tube the frequencies may be measured up to 20 megacycles, therefore all-wave service is enjoyed from this simple little instrument.

Since the fundamental range is 109 to 201 kc there is a difference of only 92 kc, hence no crowding, in fact, the bars on the 2¾-inch diameter dial are only one kc apart. The accuracy being high for the fundamental band, it is just as high for all harmonics, hence measurement of high frequencies at high accuracy is attainable, an advantage otherwise offered only by the most expensive signal generators.

While for frequencies higher than those represented by the fundamentals, 109 to 201 kc, the receiver can not be preset at a selected frequency above 480 kc, the frequency of any receiver setting can be measured. Several ways of doing this have been explained in detail in these columns, but as one way is somewhat handier and more self-checking than the others, it alone will be presented.

TABULATION OF SOLUTION

The operations are as follows:

1. Start at the lowest frequency setting of the generator, say, 109 kc, with generator coupled to the circuit to be measured. Slowly turn the dial of the generator to higher frequencies, until a response is obtained. Adjust the generator dial so that the response is clearly maximum. It is preferable to feed no more energy into the measured circuit than actually necessary for distinct aural or visual indication. Note the frequency read on the dial (upper tier of fundamentals).

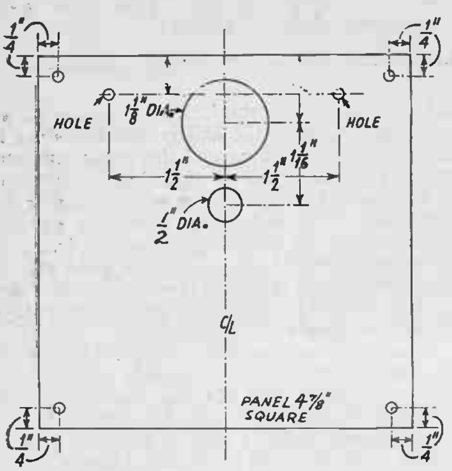
2. Now turn the generator dial to still higher frequencies, until the next consecutive re-

(Continued on following page)

(*Continued from preceding page*)

sponse is heard. Again adjust the dial for maximum response. Note the frequency as read on the dial (upper scale).

3. Now subtract the first or lower read frequency from the second or higher read frequency, yielding of course the difference between the two frequencies. Divide this difference into higher (later) frequency that you read on fundamentals, and the answer is the harmonic order of the *other*, or *lower*, frequency. Multiply this lower frequency by the harmonic order thus obtained and the accurate answer is the unknown frequency.



Dimensions for the panel. The four-corner holes are intended for self-tapping screws, to hold the panel to the metal box. The two holes to the left of the 1 1/8" diameter escutcheon opening are for binding posts, one to be conductive to box, other to be insulated for output, and 3/8" down. The center of the large hole is 5/8" from the panel top.

NUMERICAL EXAMPLE

An example will be given numerically, as if the steps were taken in the order just prescribed. The example will even include a small difficulty. Once the method is mastered it is applicable with ease and accuracy and one will feel in possession of a valuable piece of radio technique.

1. Starting at the lowest frequency of the generator, condenser plates fully in mesh, turn to higher frequencies. The first response is at a point between 118 and 119 that looks like nearly 118.5 kc, so note that frequency as 118.5 kc.

2. The second response is obtained at exactly 142 kc, so note that.

3. Subtracting the lower from the higher, 142—118.5=23.5 kc. Dividing 23.5 into the lower read frequency, or 118.5 kc, which we could read only to .5 per cent therefore may be a bit off because not falling exactly on a bar, we get 118.5/23.5=5.05. We know that harmonic orders must always be whole numbers, so despite the difficulty of reading one number as closely as desired, the harmonic order is the nearest whole number, 5, applied to the higher frequency, or the unknown is 5x142=710 kc.

ACCURACY OF .05 PER CENT

If we remember that the harmonic orders are always consecutive, when we know one we know the other. Hence we had 5 as the harmonic order for the *higher* frequency. For the lower frequency the next *higher* harmonic order, or 6, would apply, because the product with a lower fundamental is the same.

So we may determine accurately the frequency we thought was so hard to read. It was 710/6=118.333 kc. If we beat with a

station operating on any frequency we are measuring, the accuracy may be as good as that of the station, sometimes reaching .05 per cent, as then we depend on the generator for .5 per cent "approximation" and on the station crystal for the improvement of accuracy.

So there need be no concern about accuracy, provided the calibration itself is accurate to .5 per cent, and the inductance permits the frequency coincidence. The condenser is assumed to be uniform in production, which is true of condensers of highly reputable manufacture, so one need be cautious about getting an accurate coil, and adjusting the generator properly.

FREQUENCY ADJUSTMENT

The generator requires an adjustment because of the trimmer. The scale is affixed to the condenser shaft, scale being small enough to clear any chassis on which the condenser rests, and the escutcheon is adjusted so that one indicator points to 400 when the other points to 200, for there is a double-pointer escutcheon, one for the fundamentals at top of the scale, the other for the intermediate frequencies on the next tier. Then the condenser plates are entirely disengaged, minimum capacity of the condenser now in circuit, and end bar on top tier serving as indicator, and the dial is securely affixed so at minimum capacity the upper pointer indicates the end bar.

Now a station is tuned in on a set, the station frequency being one that when divided by 3, 4 or 5 yields a number equalling 190, 192, 194, 195, 196, 198, or 200. The trimmer is adjusted when the dial is made to read this lower number, until zero beat with the station is established.

To check up, divide the same station frequency by one larger number and see that this lower reading comes in where it should when the dial is turned to indicate this frequency. Still a lower number etc. may be used until the dividend is an off-scale frequency (lower than 109 kc).

SUBSTITUTION OF PARTS

In conclusion, it should be pointed out that the circuit may be built with any condenser and coil, to cover any fundamental range desired, and coils for higher capacity condensers are commercially obtainable. However, a calibration would have to be performed. For use of a pre-calibrated dial, like the one discussed, only a particular condenser may be used, as the dial reflects particular capacity changes, and the inductance is selected for frequency coincidence. This statement is made to answer those who may think that a frequency-calibrated scale may be made to apply to any condenser.

Also, it should be emphasized, the direct-reading feature renders intermediate-frequency alignment quick and easy, without computation. The numerical method for determination of station frequencies was detailed only for those who might be pressed for a higher-frequency measurement, and would not quite be able to discover the mathematical application to that solution.

Literature Wanted

Readers whose names and addresses are printed herewith desire trade literature on parts and apparatus for use in radio construction. Readers desiring their names and addresses listed should send their request on postcard or in letter to Literature Editor, Radio World, 145 West Forty-fifth Street, New York, N. Y.

Bernard Kuder, 4003 Eldorado Ave., Baltimore, Md.
W. S. Fickel, 337 Centeu St., Chula Vista, Calif.
John T. Fisher, Electro-Acoustical Engineer, 1711 W. Oxford St.. Philadelphia, Pa. Commercial electroni devices and sound equipment.
Joseph Gil-Borges, Sur 5-157, Caracas, Venezuela, So. Amer.
Santos Memendez, Moireles 2—Cerro, Habana, Cuba—oscillators, especially covering F. I. and S.W. efficiently.
Wendell Campbell, 112 Winthrop, Brookline, Mass.
McKay, Alfred, 1046 West 6 So., Provo, Utah—oscillators (kits and ready made), and other test equipment.
Robert Wray, P.O. Box 84, Red Bank, N. J.
Roy A. Wissel, 63 Danvers Ave., Ingram, Penna.
E. Fred Slater, Franklin & Marshall Academy, Lancaster, Penna.
Jules J. Dumont, Rouyn, Quebec, Canada.
E. Arnold, 344 Verona Ave., Elizabeth, N. J.
Jack McNamara, Judice Hall, S.L.I., Box 19, Lafayette, Louisiana.
Charles A. Blume, The Forvent Company, 25 Beave Street, New York, N. Y. Dial-A-Matic.
Benedict Settles, Legion Blvd., Owensboro, Ky.
Walter Klohr, Bena, Gloucester Co., Virginia—diagrams, specifications, etc., on home-built test equipment for radio servicing.
E. P. Willison, 3743 S Street, Sacramento, Calif.
Vastine Janda, Route 3, Box 12, La Grange, Texas.
Paul Aandahl, Post Box MJ 2229, Oslo, Norway.
C. Joseph Johnson, 3445 Evaline Ave., Hamtramck, Mich.
Howard E. Badger, Chariton, Iowa.
R. H. Bassett, 108 Park Terrace, E., New York, N.Y.
Harry E. Burke, 833 Brooklyn St., Philadelphia, Pa.
A. G. Bronston, 45 North Hobart St., Philadelphia, Pa.
H. E. Nixon, 208 North 58th St., Philadelphia, Pa.
Edward D. Eastlack, 1304 Virginia Ave., Manoa, Pa.
Clayton Smith, 766 Chain St., Norristown, Pa
Arthur R. Milligan, 69 Edgewood St., Pottstown, Pa.
Al. Christie, 3145 Salmon St., Philadelphia, Pa.
Percy Steelman, 21 School Lane, Ardmore, a.
John H. Bloomer, 6526 Van Dyke St., Philadelphia, Pa.
Samuel M. Costilo, 4613 Boudinot St., Philadelphia, Pa.
George B. Kerper, 7911 Queen St., Philadelphia, Pa.
Anthony Fortunato, 2728 Chestnut Ave., Ardmore, Penna.
Albert Weiss, 2319 South 9th St., Philadelphia, Pa.
M. M. Washburn, 2604 - 18th St., North, Arlington, Va.
Walt Bartholomew, Box 538, Joplin, Mo.
Rafael Frasqueri, P. O. Box 477, San Juan, Puerto Rico.
Joseph Giandonato, 92 High Street, Bridgeport, Conn.—S. W. set to get programs from Italy.
Jesus L. Serrano, 42 Paraiso Street, San Juan, Rizal, P. I.
Ed Sigman, 2nd, Op. Radio WOLNV, Shoreland Hoyel, Chicago, Ill.
Samuel Davis, 202 E. 13th St., St. Paul, Minn.
F. Dugdale, 1272 Hobart Ave., Bronx, New York.
Harold W. Granberg, c/o Gem Theatre, Balaton, Minn.
T. J. Sweeney, W8JU, 448 E. Water St., Elmira, N. Y.
A. P. Seidel, 2218 Pasadena Ave., Los Angeles, Calif.
Ralph R. Wolf, 132 Bouck Street, Tonawanda, N. Y.
T. Marsh, Jr., Cchinchilla, Penna.
Cyril M. Senkeresty, 733 North Leavitt Street, Chicago, Ill.
M. G. Sateren, 155 Boulevard St., West Springfield, Mass.
William Bollwage, 631 Magnolia Ave., Elizabeth, N. J.

Pinch-Hit Technique

Emergency Servicing When Caught Meterless

By Emil Bouchwald

IF you are unexpectedly called upon to service a radio and you have no service instruments along, do not become alarmed. A great deal can be done without meters.

The first thing to look for is smoke. Usually where there is smoke there is a burned-out power transformer. A replacement is necessary.

The next step is the rectifier tube. Metal tubes do not permit us to see much, neither is the ambient temperature any indication, since these tubes get very warm under normal load.

The high vacuum glass rectifiers will show any overload in the form of red-hot plates and a blue haze between the elements. This usually means a shorted filter condenser. Sometimes a blue haze is visible when there is no overload on the tube. This indicates a gas-filled tube, which does very little rectifying. Replace the tube.

The mercury vapor tubes will shine with a brilliant blue light upon a heavy overload, the intensity of the glow being proportional to the load. They will not stand up as long under an overload as the high vacuum type due to the low internal resistance. If the rectifier does not glow at all then the circuit is open somewhere inside the set.

ANTENNA AND B SUPPLY

Check over the antenna lead, especially the window strip. These things sometimes crack inside the insulation, opening the circuit. Remove the strip and splice the wires together temporarily.

The antenna lead may be disconnected from the radio and held on the grid cap of the first radio-frequency tube. If this brings no results then try the next tube, etc.

Plate voltage may be checked with a small piece of wire. Ground the plate contact of each tube momentarily. If a spark is visible then the voltage is apparently ok. The same idea may be tried on the screen grid connections. If no spark is visible check back for an open resistor or a shorted bypass condenser.

Distortion may be caused by a bad power output tube. Try substituting a new tube. Look for a bad electrolytic condenser. Shunt each electrolytic with another of known quality for a moment.

Weak signals are caused by a number of things, among them being an open bypass condenser. Shunt each bypass momentarily with a good one.

Fading signals are sometimes caused by defective coupling condensers in the audio amplifier, i.e., the condenser connected between the plate of one tube and the grid of the next tube. A condenser in a radio-frequency circuit will sometimes defy the usual tests and still cause fading in the set. In both cases just mentioned, substitute is advisable until the bad one is found, and replace.

NOISE SOURCE TRACKED DOWN

Noise may be caused by a tube with loose elements. Turn on the radio and tap each tube lightly with a screw driver or any other implement you may have on hand. This method will usually show up a noisy tube which indicates "good" on a tube tester.

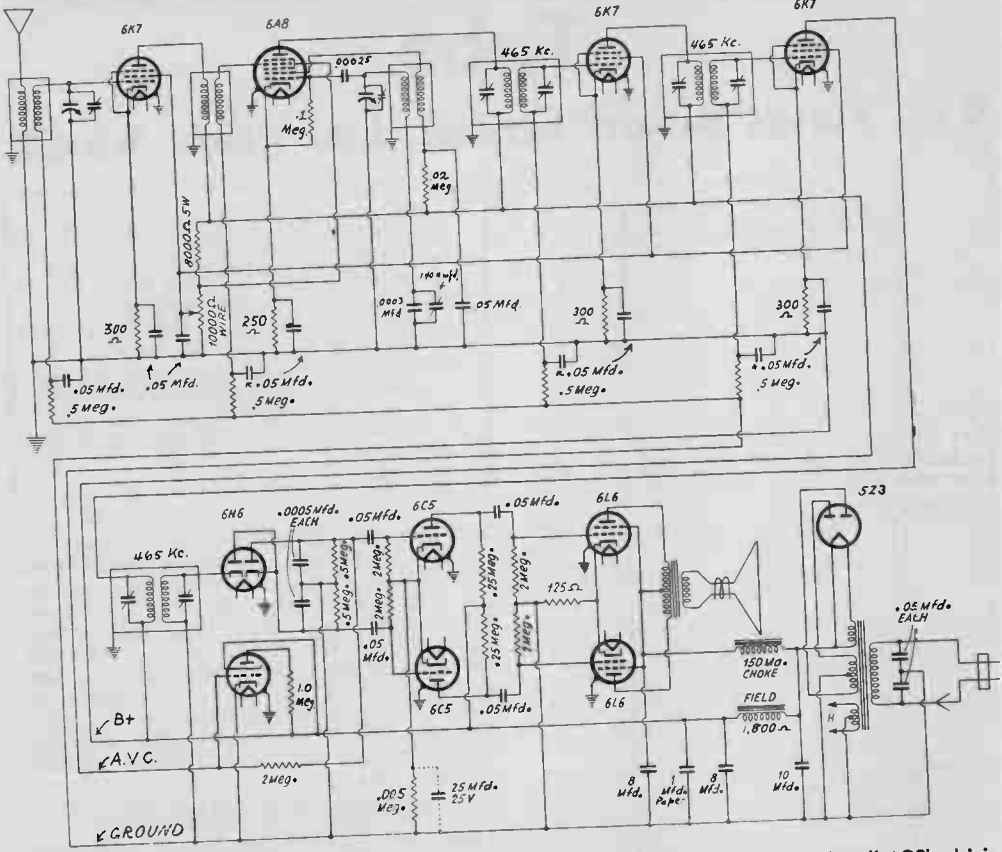
The origin of noise may be determined by disconnecting the antenna. If the noise ceases then it comes from outside. If it persists then it is within the set.

On a superheterodyne it may happen that stations come in fine over a portion of the dial, the rest of the dial being dead. Try another oscillator tube. In the tuned-radio-frequency job the trouble may be alignment. The variable condenser can be aligned fairly well by ear until the necessary oscillator and output meter can be procured. Start at the high-frequency end of the dial when aligning the condenser as better results usually accrue.

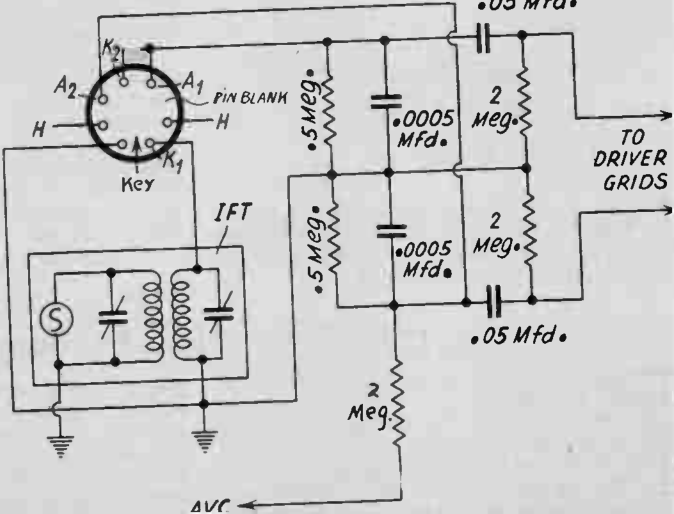
N.U. Seeks New Products

National Union Radio Corporation of N. Y. announced the appointment of J. H. Robinson as director of new products research. Mr. Robinson assumes the new title and duties, in addition to his regular work as export manager. He has been assigned the task of seeking out and analyzing the marketability of new products, patents and ideas having to do with radio, electronics, television and electrical industries. Inventors are invited to correspond in strict confidence with Mr. Robinson, c/o National Union Radio Corporation, 570-A Lexington Avenue, New York, N. Y., before January 1st.

Volume Expander



The LaFrance balanced detector is featured in this superheterodyne, which has push-pull 6C5's drivin push-pull 6L6 output tubes. The power output is 15 watts at less than 4 per cent. total distortion. Th tube at lower left is a 6G5 ray indicator. The circuit and its performance will be discussed in detail next month in the January issue.

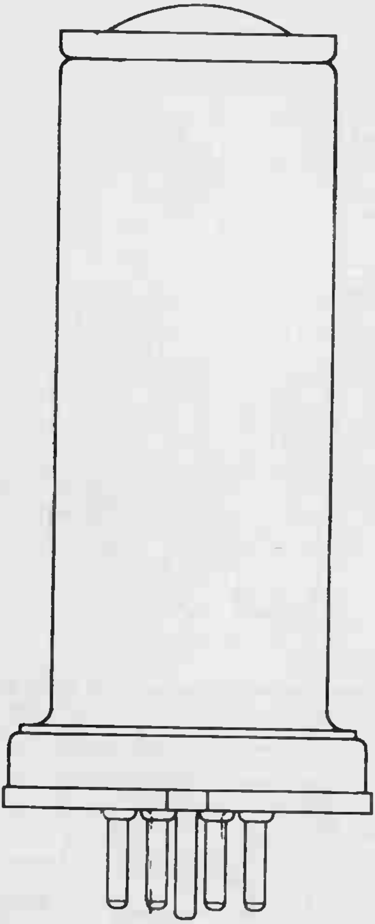


The connections to the 6H6 socket. Bottom view of the socket gives the location of key, seven pins and blank. The standard pin numbers, reading clockwise from the key, are 1, 2, 3, 4, 5 (6 blank), 7 and 8. The last i.f. transformer is shown at bottom left. Output of the balanced detector connects to grids of the 6C5 driver tubes.

New, Small Cathode-Ray Tube

913 Yields Bright Screen; List Price, $5.60

> *Many, who have realized the advantage of a cathode-ray oscillograph, but who did not feel they could afford the standard models using a 3-inch or larger tube, will be greatly interested in a new, small tube, viewing space* 15/16 *inch diameter, that operates on* 250 *to* 500 *volts and is low in cost. Such a tube, the* 913, *is now announced by RCA Manufacturing Co., Inc., and is described in the accompanying article. Unofficial list price is* $5.60.
> —EDITOR.



Actual size of the 913. It is in a metal shell, with octal base, but the top is open to view, through a fluorescent glass screen. The actual width of the exposure for viewing is $\frac{15}{16}$ inch.

THE 913 is a high-vacuum cathode-ray tube utilizing the all-metal construction and having a fluorescent viewing screen approximately one inch in diameter.

This tube, designed for operation with an anode voltage as low as 250 volts, is provided with two sets of electrostatic plates for deflection of the electron beam. The 913 produces a brilliant, luminous spot having a greenish hue.

This new type greatly enlarges the field for practical applications of the cathode-ray tube.

The electron source of the 913 is a substantial cathode indirectly heated. The cathode, control electrode (grid), and focusing electrode which functions also as an accelerating electrode, constitute an electron gun for projecting a beam of electrons upon the fluorescent screen. The resulting luminous spot, easily visible in a well-lighted room, can be regulated as to size and intensity by suitable choice of electrode voltages.

SUITABLE FOR SMALL RIGS

The two interconnected sets of electrostatic plates in the 913 produce fields at right angles to each other, and consequently deflections at right angles. One set serves to reproduce the phenomena under observation; the other is used for the time sweep.

Because of its unusually small size and its ability to produce a bright image at extremely low voltages, the 913 is especially suited for compact, portable, oscillographic equipment. These features, in addition to the relatively low cost of the 913 and its associated apparatus, make this tube practicable for use in many types of test equipment where a larger cathode-ray tube would not ordinarily be employed.

INSTALLATION DIRECTIONS

The *base* pins of the 913 fit the universal eight-contact octal socket, which may be installed to hold the tube in any position.

The *metal shell* of the 913 is connected to anode No. 2 within the tube. In circuits where it is desired to operate the shell at a positive potential with respect to chassis ground, the shell should be entirely encased in a cylindrical tube of good insulating material. Bakelite or fibre tubing, is suitable for this purpose. The front rim of the metal shell should also be

TENTATIVE CHARACTERISTICS

Heater Voltage (a.c. or d.c.)	6.3	Volts
Heater Current	0.6	Ampere
Fluorescent-Screen Material	Prosphor No. 1	
Direct Interelectrode capacitances:		
Control Electrode to All Other Electrodes	10.5 *max.*	mmfd.
Deflecting Plate D_1 to Deflecting Plate D_2	3.6 *max.*	mmfd.
Deflecting Plate D_3 to Deflecting Plate D_4	4.3 *max.*	mmfd.
Maximum Overall Length	4-3/4"	
Maximum Diameter	1-23/32"	
Base (For connections see diagram of bottom view)	Octal 8-pin	

MAXIMUM RATINGS and TYPICAL OPERATING CONDITIONS

High-Voltage Electrode (Anode No. 2) Voltage	500 *max.*		Volts
Focusing Electrode (Anode No. 1) Voltage	125 *max.*		Volts
Control Electrode (Grid) Voltage	Never Positive		
Grid Voltage for Current Cut-off*	—90 *approx.*		Volts
Peak Voltage Between Anode No. 2 and Any Deflecting Plate	250 *max.*		Volts
Fluorescent-Screen Input Power per Sq. Cm.	5 *max.*		Milliwatts
Typical Operation:			
Heater Voltage	6.3	6.3	Volts
Anode No. 2 Voltage	250	500	Volts
Anode No. 1 Voltage**	50	100	Volts
Grid Voltage	Adjusted to give suitable luminous spot		
Deflection Sensitivity:			
Plates D_1 and D_2	0.15	0.07	Mm/Volt d.c.
Plates D_3 and D_4	0.21	0.10	Mm/Volt d.c.

---

* With approximately 100 volts (to focus) on Anode No. 1.

** Approximate.

made inaccessible by means of a clear celluloid or glass plate mounted in front of the viewing screen. Where a separate d.c. power supply is used for the electrode voltages (see circuit), it is recommended that the shell be grounded, rather than the cathode terminal. With this method, which places the cathode and heater at a high negative potential with respect to ground, the shell need not be insulated from the chassis and the high voltage can more easily be made inaccessible. If the shell of the 913 can not be connected to the chassis, as is the case where the anode No. 2 voltage is obtained from the power supply of a receiver or other equipment, d.c. blocking condensers (C_2, C_3 and C_4 in the circuit) must be inserted in the signal-input leads to both sets of deflecting plates, so that the anode voltage supply can not be shorted by the signal circuit.

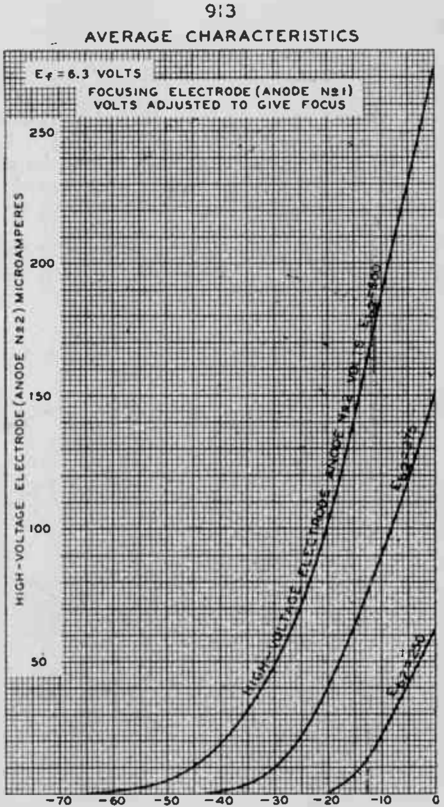
The *heater* is designed to operate at 6.3 volts. The transformer winding supplying the heater power should be designed to operate the heater at the rated voltage under average line-voltage conditions. *If the circuit design is such as to cause a high voltage between the heater winding and ground, the heater transformer should be adequately insulated to withstand the high voltage.*

The *cathode* is connected within the tube to one side of the heater. The terminal for this common connection is base pin No. 2, to which grid and anode returns should be made.

The *fluorescent* screen employed in the 913 is of the phosphor No. 1 (medium persistence) type. It has good visual properties as well as high luminous efficiency.

The *d.c. supply voltages* for the electrodes may be conveniently obtained from a vacuum-tube rectifier. Since a cathode-ray tube requires very little current, the rectifier system can be of either the half-wave or the voltage-doubler type. For the same reason, the filter requirements are simple. A 4 to 8 mfd. condenser will

(*Continued on following page*)



The control electrode (grid) volts compared to the current through the high-voltage (Anode No. 2) electrode. The d.c. high voltages are 500, 375 and 250 volts, with a curve for each. For a given combination the adjustment to give focus is disclosed.

(Continued from preceding page)

ordinarily provide sufficient filtering. If this is inadequate for a particular application, a two-section filter is recommended.

HOW DEFLECTION ARISES

Two sets of *electrostatic plates,* producing fields at right angles, provide for deflection of the electron beam. The electrostatic field of each pair of deflecting plates deflects the beam parallel to the axis of the field; therefore, the deflections produced by the two fields are at right angles. One deflecting plate of one set is connected within the tube to one plate of the other set, to anode No. 2, and to the shell.

In order to maintain the free plate of each set at essentially the d.c. potential of anode No. 2, each of these plates should be connected through a resistor of 1 to 10 meg. to the anode No. 2 socket terminal. This arrangement permits choice of resistor value such that the electron beam is not distorted by d.c. potentials built up on the deflecting plates.

If, during operation, the zero axis should be permanently deflected, it is usually because the beam current is too high for the resistors used. The beam current should ordinarily be kept low.

In cases where the fluorescent spot is off center, a variable d.c. bias voltage of the necessary polarity should be connected in series with one or both of the deflecting-plate resistors (at points marked "x" in the circuit). The polarity of each control voltage should be such that the spot can be shifted in the desired direction, or preferably, in both directions so as to provide a pattern-centering adjustment.

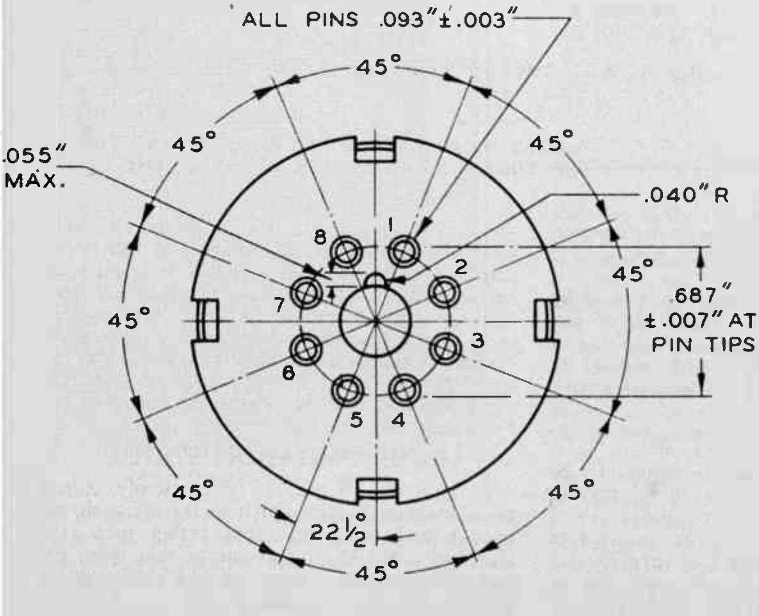
The *deflection sensitivity* for each set of plates for typical anode No. 2 voltages is given under Maximum Ratings and Typical Operating Conditions.

The voltages at which the 913 is operated may be dangerous. Care should be taken in the design of apparatus to prevent the operator from coming in contact with these voltages. Precautions include the enclosing of high-potential terminals and the use of "interlock" switches to break the primary circuit of the high-voltage power supply when access to the apparatus is required. In circuits where the shell can not be connected to the chassis, it is important that the shell be *completely insulated* as described in the second paragraph under Installation.

In the use of cathode-ray tubes, it should always be remembered that high voltage may appear at normally low-potential points in the circuit, due to condenser breakdown or to incorrect circuit connections. Therefore, before any part of a cathode-ray tube circuit or its associated circuit is touched, the power-supply switch should be turned off and both terminals of any charged condensers grounded.

APPLICATION OF THE 913

The cathode-ray oscillograph is an instrument adaptable to a wide variety of applications. A few of the more important are: the study of wave shapes, measurement of modulation and peak voltages, adjustment of and location of faults in radio receivers and a-f amplifiers, comparison of frequencies, and the indication of balance in bridge circuits. Due to the relatively low cost of the 913 and its associated apparatus, to the low voltages at which it can be operated, and to the small size and portability of equipment in which it is employed, this tube should find very general use by engineers, radio



BOTTOM VIEW OF BASE

PIN NUMBERS AND ELEMENTS

1—Anode No. 2, deflecting plates D_2 and D_4, and shell.
2—Heater and cathode.
3—Anode No. 1.
4—Deflecting plate D_1.
5—Grid.
6—Deflecting plate D_3.
7—Heater.
8—Tied within tube to Pin No. 1.

servicemen, radio amateurs, and school laboratories.

A diagram illustrating the *essential circuit* for the use of the 913 in an oscillograph is shown. The electrode voltages are obtained from a bleeder circuit connected across the high-voltage supply. A bleeder current of 2 or 3 milliamperes is usually satisfactory; considerably larger values may require the use of more filtering than that provided by a single condenser shunted across the d.c. supply. With small bleeder currents, a single condenser filter is usually adequate. A variable d.c. voltage for the control electrode and for anode No. 1 can be obtained from potentiometers in the bleeder circuit. One set of electrostatic deflecting plates is used for the phenomena under observation; the other set, for the time sweep which serves to spread the tracing across the fluorescent screen.

Focusing of the fluorescent spot produced by the beam is controlled by adjustment of the ratio of anode No. 2 voltage to anode No. 1 voltage. Ordinarily, the ratio is varied by adjustment of anode No. 1 voltage, as shown in the circuit diagram.

SPOT SIZE AND INTENSITY

Regulation of *spot size* and *intensity* can be accomplished by varying anode No. 2 current and/or voltage. The current to anode No. 2 may be increased by decreasing the bias voltage applied to the control electrode (grid). An increase in anode No. 2 current increases the size and intensity of the spot. An increase in the voltage applied to anode No. 2 increases the speed of electrons which increases spot intensity and decreases spot size. When any of these adjustments are made, consideration should be given to the limiting voltage and power ratings shown under Maximum Ratings and Typical Operating Conditions.

In applications involving *voltage measurements*, the anode No. 2 current should be reduced to the minimum value consistent with the desired brilliance of pattern. Where high brightness is an important consideration, the voltage applied to anode No. 2 may be increased to the maximum rated value. This procedure, however, is not always desirable because the greater speed of the electrons in the beam causes reduced deflection sensitivity.

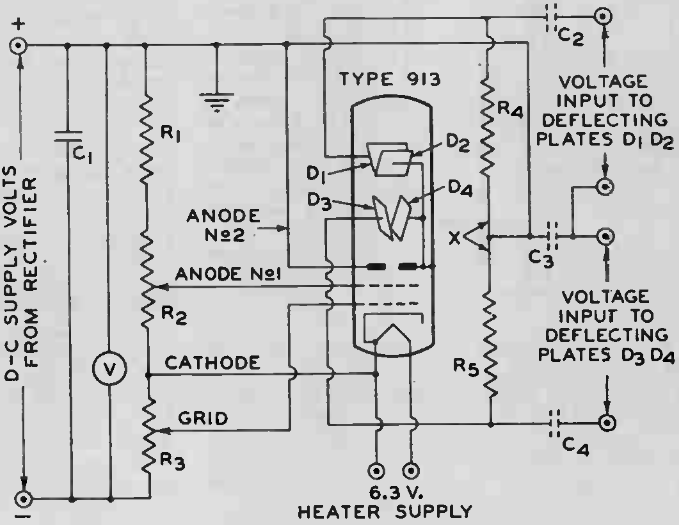
The 913 is designed to provide as high a current in the electron beam as is consistent with good focusing qualities. This high current capability is a distinct advantage for obtaining bright patterns covering a relatively large area, but must be used with caution when the spot traverses slowly any portion of a large pattern or when the pattern size is small. Where recurrent phenomena are involved, a pattern, or some portion of it, having too high a power input per unit area may cause the rating of the fluorescent screen to be exceeded.

INPUT LIMITATION STATED

A "slowly-moving spot" is tentatively defined as a fluorescent spot which is traveling slowly enough to be seen as a spot, rather than as a trace or line. With patterns of this type, the power input to the screen should be limited as in the case of a stationary spot.

It is important that the maximum input

(Continued on following page)



C_1 = FILTER CONDENSER – 4 TO 8 μf
C_2, C_3, C_4 = 0.1 μf
R_1 = 130000 OHMS, 2 WATTS
R_2 = 40000 OHMS
R_3 = 30000 OHMS
R_4, R_5 = 1 TO 10 MEG.

NOTE : PLATES D_2 AND D_4 ARE CONNECTED WITHIN THE TUBE TO ANODE Nº 2 AND THE SHELL.

A typical circuit for using the 913 cathode-ray oscillograph tube. If a separate power supply is used the three .1 mfd. condensers, C_2, C_3 and C_4, may be omitted. "Separate" means the power supply is used for cathode-ray tube exclusively.

The Prison Gun Detector

Electromagnetic Device Discloses Metal Generally

By David G. C. Luck and Charles J. Young

RCA Manufacturing Co., Inc.

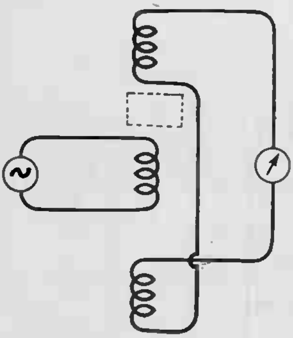


FIG. 1
The fundamental circuit of induction balance. An alternator (left) feeds a single primary or driver coil, which fills the region to be explored with a magnetic field of moderately uniform intensity.

THE development of the detector described in this article originated with a request for a method of inspecting prisoners and prison visitors for concealed weapons, especially guns. The resulting study of the general problem of detecting metallic bodies within a specified region culminated in the design of a commercial Gun Detector. This apparatus is now installed in a number of prisons and is proving very useful. An analysis of the means for solving the problem will be given first, followed by a description of the actual unit.

The properties which are common to most metals, and on which a detecting device might be based, are high density, electrical conductivity and, in many metal objects, high magnetic permeability.

The most obvious method of discovering such objects would depend on their high density and would be an X-ray tube and fluorescent screen. Such a system is expensive and delicate and its continued use for detecting objects carried by persons might involve some danger to those inspected. Devices indicating metallic objects by disturbance of an electric field (capacitance change) are subject to spurious effects from any large mass of dielectric material accompanying the metal. A steady magnetic field is disturbed by a piece of ferromagnetic material, but the magnetometer necessary to detect such a disturbance is a delicate instrument. Obviously, therefore, no one of these three detection systems is particularly satisfactory.

INCREASE AND DECREASE

A conducting object placed in an alternating magnetic field decreases the energy stored in the field and results in energy dissipation; that is, the inductance of a coil producing an alternating magnetic field is reduced and its resistance is increased by the presence of a conducting object. A ferromagnetic object, on the other hand, increases the energy in the field and so increases the inductance as well as the resistance of the field-producing coil. The effect of a non-magnetic object, which is a result of eddy currents induced in the object, increases rapidly with increasing frequency, so that a high frequency field should be used for the detection of such bodies. The inductive effect

(*Continued on following page*)

(*Continued from preceding page*)

power to the fluorescent screen should not exceed 5 milliwatts per square centimeter. The use of screen-input power in excess of this value will adversely affect the fluorescent coating, depending upon the magnitude and duration of the power input. The resultant injury to the screen may be a temporary loss of sensitivity, or a permanent destruction of the active screen material.

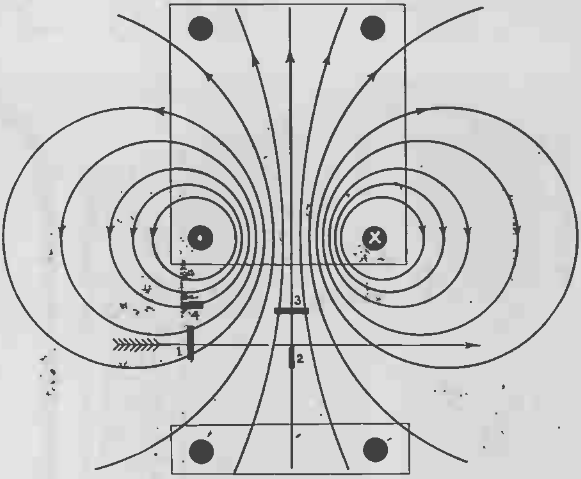
A high-intensity spot should be kept in motion by the application of voltage to the deflecting system, in order not to exceed the maximum fluorescent-screen input rating. Until this voltage is applied, the screen input power should be kept low, either by the application of a high negative control-electrode bias or by removal of the voltage from anode No. 2. Photographs of recurrent phenomena (producing stationary patterns) appearing on the viewing screen of the 913 can be made with an ordinary camera. Due to the low anode voltage and moderate screen-input power at which the 913 is operated, the photographing should be done in subdued light in order to obtain as much contrast as possible between the fluorescent pattern and the background. The time of exposure will depend upon the speed of the camera lens, the kind of film or plate emulsion used, the magnification of the pattern, and the brightness of the image on the viewing screen. Verichrome film gives excellent results.

caused by the permeability of a ferromagnetic object is opposed by the effect of its conductivity and does not depend on frequency, so that a low frequency field is desirable for the detection of magnetic bodies.

Change of inductance of a coil producing a magnetic field in a region to be searched for metallic bodies may be shown by the resulting change in frequency of a self-excited oscillator driving the coil, or by the unbalance of a bridge circuit. An oscillator is a complicated dynamical system and is inherently unstable, though care in design may do much to counteract this disadvantage; the bridge, on the other hand, is a passive network of high inherent stability. As either method of detection may be so refined as to have very high sensitivity, the bridge, being the more stable, is the more desirable. The bridge has the further advantage of being sensitive to resistance changes as well as inductance changes. The change in self-inductance of a coil when metal is brought near it is a measure of the change in total field energy; if a region about the size of a man is to be searched for small objects, the fractional change in total field energy to be detected is extremely small.

FIG. 2.

The field distribution in the coil system. It is necessary to establish such a field so that a metal object in any position in respect to the field will be detected. The round black spots represent the intersection of the coil windings with the plane of section, and the small black rectangles are sections of metallic objects placed in in the field.



A second coil immersed in the magnetic search field will be coupled to the exciting coil to a degree depending not only on the total field energy but also, very markedly, on the distribution of the magnetic flux; thus, a metallic object, altering slightly the direction of the magnetic flux lines, can produce a much greater fractional change in the mutual inductance between two coils than in the self-inductance of either of them. Because mutual inductance can be negative, the usual four-element bridge network can, in this case be reduced to a two-element form known as an "induction balance." Use of an induction balance for metal detection is quite old[1], but the devices used do not seem to have been highly developed. Application of modern methods and equipment to the induction balance principle seems to the authors to provide the best general solution of the metal detection problem.

The fundamental induction balance circuit is shown in its simplest form in Fig. 1. Here, an alternator feeds a single primary or driver coil which fills the region to be explored with a magnetic field of moderately uniform intensity. On the opposite side of the protected region, indicated by the dotted rectangle, from the primary coil is placed a secondary or pickup coil. This coil is connected in series with a similar pickup coil of opposite polarity, occupying a symmetrical position in the primary field, and with an indicating instrument.

Placing driver and pickup coils on opposite sides of the protected region is rather an innovation in metal detection and increases the sensitivity markedly over that obtained with older devices having the entire coil system off at one side of the region of interest. If all three coils were coincident, obviously no differential change in the two mutual inductances could be produced by introduction of metal into the field; similarly, little differential change could occur with very widely separated coils. The maximum effect may be expected for separations comparable to the dimensions of the coils, which fact helps to determine the coil dimensions required for different applications.

FIELD FROM ALL DIRECTIONS

It is not surprising to find that the effect of a magnetic object is determined largely by its extension in the direction of the magnetic field, and that of a non-magnetic object primarily by its area transverse to the field. Therefore, to insure detection of an object in any position, it is necessary to pass it through the protected region in such a way as to cause encounter with field proponents in every direction. This is illustrated by Fig. 2, which

(*Continued on following page*)

---

[1] C. Gutton, Comptes Rendus, *161*, 71 (1915).

(*Continued from preceding page*)

shows the magnetic field pattern in a plane section through the common axis of the three coils; the round black spots represent the intersection of the coil windings with the plane of section, and the small black rectangles are sections of metallic objects placed in the field.

A magnetic object in position 2 gives a relatively large unbalance, while the same object in position 3 has very little effect; thus, an object carried in position 3 along the axis of the coil system might pass through the apparatus undetected. On the other hand, an object in position 1 has little effect, but if carried without turning in the direction of the arrow, a considerable unbalance will occur when position 2 is reached; likewise, the object shown at 3 will produce unbalance when such a position as 4 is reached. It is thus possible to insure detection of an object pointing in any direction in the plane of the figure by carrying it through the coil system in the direction of the arrow. The housing indicated by the light lines in Fig. 2 serves a threefold purpose: it prevents mechanical disturbance of the coils themselves, it keeps foreign objects out of the region between the primary coil and the compensating secondary coil, and it forces material undergoing inspection to be carried through the apparatus in the proper direction.

FIG. 3. One form of mounting is shown for the three coils or loops. Three heavy plywood panels support the frames and protect them from accidental physical contacts as the suspect moves between two loops.

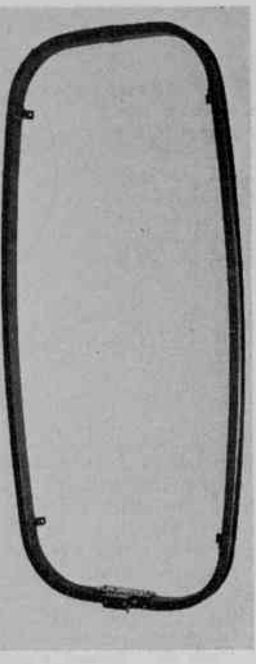


FIG. 4. The coil structure is shown at right, representing an improvement over the method shown in Fig. 3. The rounded rectangle is made of aluminum channel.

STRAYS CONSIDERED

The large coils needed to give reasonably uniform sensitivity over a region the size of a man are quite expensive, so it may appear strange that some small scale mutual impedance is not substituted for the third coil, which besides its cost is very wasteful of space. The main reason is that in most places considerable stray magnetic fields are present to interfere with operation of the device and that the use of two similar coils connected in opposition cancels out the effect of the spatially uniform portion of such stray fields and so greatly reduces the interference level. A further reason is that the high electrical and mechanical symmetry of the system shown results in a considerable stability of balance with respect to such disturbing events as electrical surges, temperature changes and so forth.

SIZE OF PROTECTED REGION

The requirement that the unbalance signal output from the pickup coils resulting from the presence of some definite small metal object in the protected region shall always exceed the interference output can only be met by the provision of a sufficiently strong primary field. In particular, at small field strengths the permeability of many ferromagnetic materials increases linearly with the field strength, so that the signal output resulting from a magnetic body in the field increases approximately as the square of the primary field, as shown by some recent experiments made by R. D. Serrell. Now, for a given size of protected region, the square of the field strength is proportional to the reactive power stored by the primary coil, so that for any given protected region and interference level, the useful sensitivity can only be increased by increasing the volt-ampere-reactive rating of the driver coil. The requirement of large reactive power immediately suggests the desirability of using the 60-cycle supply as a power source and resonating the driver coil to prevent a large reactive load on the supply line.

MOUNTING METHODS

It will be of interest now to proceed from this analysis of the problem to a picture of the form in which the apparatus is actually built. Fig. 3 shows one form of mounting for the three coils or loops. Three heavy plywood panels support the loop frames and protect them from accidental physical contacts as the suspect moves through the passage between the central power loop and the near pickup loop. Such protection is essential as a very slight distortion of the coils will cause an unbalance and a consequent false alarm. The opening on the other side of the driver coil is normally closed, the panel being removed here to show the rear pickup coil. In order to obtain a normal sized doorway the coils are 6½ feet high, 3 feet wide and are mounted on 3 foot centers.

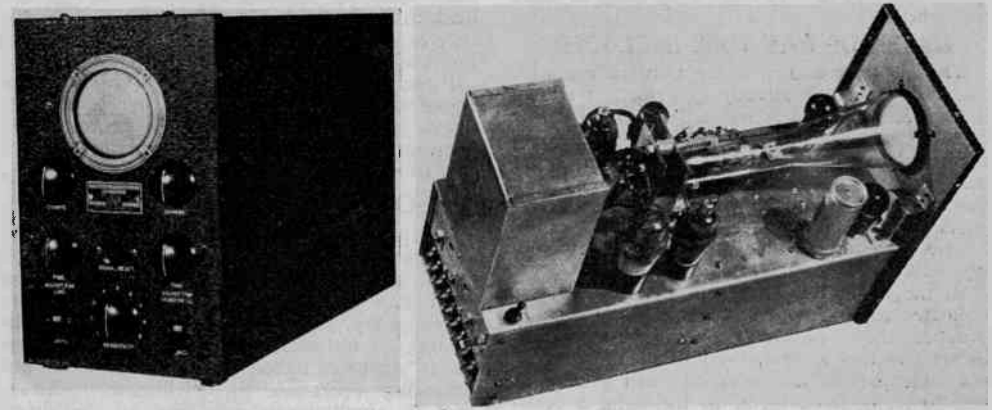


FIG. 5

The amplifier and indicator unit, external and internal views shown, is used with the loop structure. There are five tubes, including a three-inch cathode ray tube.

The structure of the coils is shown in Fig. 4, which represents a distinct improvement over the earlier model of the preceding figure. The form in which the winding is placed is a rounded rectangle made of aluminum channel. It is simple to manufacture, and because of the curved sides the wire is easily wound and stays tight in the form. The same form is used with different windings for the power coil and for the pickup coils.

BLACK LACQUER'S EFFECT

The winding specification for the power coil is determined, as would be expected, by a proper compromise between manufacturing and operating costs. As has been pointed out, the reactive power storage required in the driver coil depends on the interference from stray fields. It was found that 1,200 ampere turns were sufficient to permit the reliable detection of small revolvers under normal interference conditions. For a coil size of 6½ feet by 3 feet, 1,200 a.t. corresponds to a reactive power of about 2 kilowatts.

It is apparent that this value of ampere turns can be obtained either with a coil of small winding section and consequent low manufacturing costs and high operating costs, or with a coil of large section having high first cost and low operating cost. The lower limit of the coil winding section depends on the permissible heat dissipation and the upper limit is determined largely by the physical size and the manufacturing cost. Temperature runs with a power coil mounted in a typical enclosed structure indicated that 650 watts was about the maximum practicable input. Good ventilation cannot always be secured and the surrounding structure may be of wood. It is interesting to note that the temperature rise is materially reduced by providing a rough black lacquer surface.

The number of turns for the power coil depends on the way it is supplied from the 110-volt line. If simply connected across the line it will be found that an excessive reactive current is required through relatively few turns. Parrallel tuning to correct the power factor would require several hundred microfarads of low voltage capacitors, an uneconomical form of energy storage. Consequently, at this supply voltage, series tuning of the power coil circuit is the only satisfactory solution.

If the maximum permissible watts dissipation is taken as 650 and the maximum line voltage as 120, the resonant current in the series tuned circuit is fixed at 5½ amperes. Thus at least 240 turns are needed on the coil to provide 1,200-ampere turns at normal supply voltage. The actual number of turns was increased to 275, at which point the condenser voltage reached the maximum allowable for the chosen type. The current in the coil was limited to the desired value by correct choice of wire size. Consideration was also given to con-

(Continued on following page)

(*Continued from page* 54)

collapse the ellipse to a straight line, while motion of the reactive balance control will tilt this line to a horizontal position, corresponding to a condition of complete balance. The fully phase-sensitive cathode ray balance indicator here described is exceptionally convenient for use with any type of impedance bridge or alternating potential comparator, having as sole disadvantage a lack of inherent discrimination against obscuring of the balance point by harmonic unbalance voltages.

VOLTAGE SOURCES

In the circuit of the amplifier as shown in the schematic diagram the vertical deflection plates are excited through a coupling condenser from the amplifier unbalance voltage appearing on the grid of the relay tube. The voltage for the horizontal deflecting plates is obtained from a resistance divider supplied from the power transformer through a blocking condenser. Thus this excitation is in phase with the field of the driver coil. From the same source the control grid, in parallel with a resistor, is fed through a small capacitor, giving a grid voltage in quadrature with the field.

The remainder of the diagram is conventional except for two details of interest. The first is the use of a voltage limiting glow tube permanently connected across the secondary of the input transformer. The need of this was discovered when a small iron truck passed the loop structure, generated an unbalance of 50 volts, and broke down the transformer secondary and tuning condenser. The second feature is the grid bias network on the amplifier tube. This eliminated the need of the usual cathode resistor by-pass condenser, which becomes very large for 60-cycle amplification. Four potentiometer controls are shown which adjust voltages on the cathode ray tube to center the pattern on the screen, and to set focus and intensity of the spot. The signal setting control is adjusted so that the relay tube will trigger when the pattern on the screen spreads to a height of about ½ inch. This permits readjustment for drifts in the balance with temperature, line voltage and so on, without setting off the alarm. All of these potentiometer adjustments are at the rear of the chassis.

Because of the high degree of electrical symmetry in the device, changes of line voltage have relatively little effect. Slow changes of 15 per cent. are hardly noticeable, while even sudden changes of 30 per cent. affect the balance only moderately. The most serious effect of frequency changes is to produce interlocking of the balance controls because of phase shift in the various resonant circuits.

HIGH SENSITIVITY POSSIBLE

It is interesting to note the very great sensitivity which can be obtained from this detector when low interference levels permit the use of full gain. For example, an oscillograph pattern ⅛ inch wide, corresponding to a deflecting voltage of about 2.6 volts r.m.w.s. or an induced secondary voltage of 30 microvolts is easily observable. Such an induced voltage results at a frequency of 60 cycles per second with the 300-turn coils used, from a difference in flux linking the two pickup coils of 0.027 maxwell r.m.s.; the primary coil of 275 turns carrying 5 amperes produces a flux of about 560,000 maxwells r.m.s. An unbalance of one part in twenty millions is thus easily observable. At such sensitivities masses as small as shoe nails in the protected region begin to be indicated while such objects as a small gun or a set of brass knuckles give a tremendous effect. This, however, is an exceptional condition.

In the normal installation the device is adjusted to give the alarm on the smallest types of guns. Unfortunately, this same sensitivity will also detect such bodies as tobacco tins, spectacle cases, trusses and, in particular, steel arch supports which many people unknowingly wear in their shoes. This fact limits the major usefulness of the device to conditions under which the cause of each alarm can be investigated and some embarassment to innocent persons is not a disadvantage. That is, such a device as this is useful for prevention of arms smuggling into penal institutions or of metal pilfering from industrial plants, as well as for detection of foreign metal in packaged goods such as foodstuffs or textiles; but it is of little use for purposes like protection of commercial banks or stores from armed robbery.

[From RCA Review]

ply as a power source and resonating the driver coil to prevent a large reactive load on the supply line.

MOUNTING METHODS

It will be of interest now to proceed from this analysis of the problem to a picture of the form in which the apparatus is actually built. Fig. 3 shows one form of mounting for the three coils or loops. Three heavy plywood panels support the loop frames and protect them from accidental physical contacts as the suspect moves through the passage between the central power loop and the near pickup loop. Such protection is essential as a very slight distortion of the coils will cause an unbalance and a consequent false alarm. The opening on the other side of the driver coil is normally closed, the panel being removed here to show the rear pickup coil. In order to obtain a normal sized doorway the coils are 6½ feet high, 3 feet wide and are mounted on 3 foot centers.

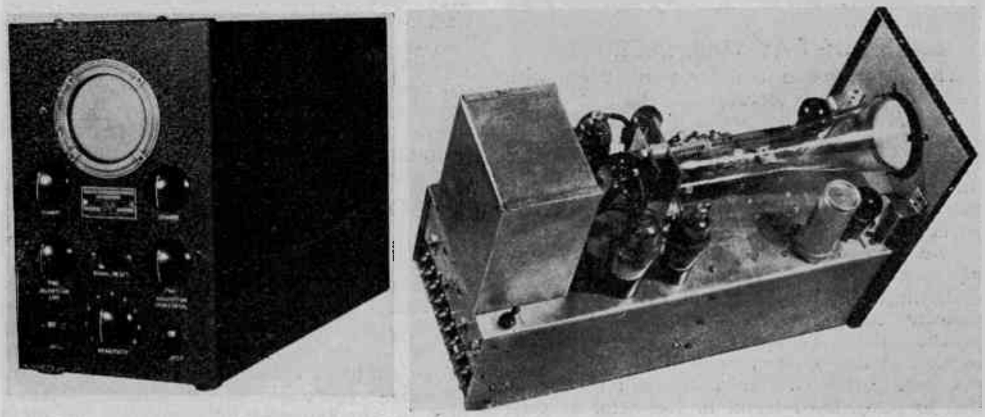


FIG. 5

The amplifier and indicator unit, external and internal views shown, is used with the loop structure. There are five tubes, including a three-inch cathode ray tube.

The structure of the coils is shown in Fig. 4, which represents a distinct improvement over the earlier model of the preceding figure. The form in which the winding is placed is a rounded rectangle made of aluminum channel. It is simple to manufacture, and because of the curved sides the wire is easily wound and stays tight in the form. The same form is used with different windings for the power coil and for the pickup coils.

BLACK LACQUER'S EFFECT

The winding specification for the power coil is determined, as would be expected, by a proper compromise between manufacturing and operating costs. As has been pointed out, the reactive power storage required in the driver coil depends on the interference from stray fields. It was found that 1,200 ampere turns were sufficient to permit the reliable detection of small revolvers under normal interference conditions. For a coil size of 6½ feet by 3 feet, 1,200 a.t. corresponds to a reactive power of about 2 kilowatts.

It is apparent that this value of ampere turns can be obtained either with a coil of small winding section and consequent low manufacturing costs and high operating costs, or with a coil of large section having high first cost and low operating cost. The lower limit of the coil winding section depends on the permissible heat dissipation and the upper limit is determined largely by the physical size and the manufacturing cost. Temperature runs with a power coil mounted in a typical enclosed structure indicated that 650 watts was about the maximum practicable input. Good ventilation cannot always be secured and the surrounding structure may be of wood. It is interesting to note that the temperature rise is materially reduced by providing a rough black lacquer surface.

The number of turns for the power coil depends on the way it is supplied from the 110-volt line. If simply connected across the line it will be found that an excessive reactive current is required through relatively few turns. Parrallel tuning to correct the power factor would require several hundred microfarads of low voltage capacitors, an uneconomical form of energy storage. Consequently, at this supply voltage, series tuning of the power coil circuit is the only satisfactory solution.

If the maximum permissible watts dissipation is taken as 650 and the maximum line voltage as 120, the resonant current in the series tuned circuit is fixed at 5½ amperes. Thus at least 240 turns are needed on the coil to provide 1,200-ampere turns at normal supply voltage. The actual number of turns was increased to 275, at which point the condenser voltage reached the maximum allowable for the chosen type. The current in the coil was limited to the desired value by correct choice of wire size. Consideration was also given to con-

(Continued on following page)

(*Continued from preceding page*)

trolling the current by a certain amount of detuning of the circuit. This was found undesirable because variations of capacity within the commercial tolerances caused marked phase change of the current and made balancing difficult.

The requirements of the pickup coils are less exacting. The amount of power is extremely small, and the voltages across the coil and between the coil and frame are less than a hundred volts. The only requirements are that the impedance of the two coils match the input impedance of the amplifier unit, and that the losses be kept as low as is economically feasible. Experience shows that tuning to 60 cycles greatly reduces interference from stray fields at other frequencies.

CATHODE RAY TUBE INCLUDED

The amplifier and indicator unit for use with the loop structure already described is shown in Fig. 5. Four tubes and a three-inch cathode ray tube are employed. The parts are chosen for reliability and long life as such an equipment may be operated many hours a day. In the schematic diagram of Fig. 6 the active parts of the circuit are generally shown in heavier lines than the associated power supply network.

In the upper left corner of the diagram are indicated the pickup loops and power loop. In practice there is always some residual unbalance in this system, even when undisturbed. As some part of the unbalance will usually be due to stray fixed metal in the field, a resistive unbalance may be expected; this component can be nullified by adjusting the losses in one or both secondary coils by rheostats connected in parallel with the coils.

The obvious means of compensating inductive unbalance is a mechanical adjustment of coil position; it is, however, possible to use an adjustable capacitor shunted across one coil to accomplish the desired result. The use of adjustable shunt capacitors and resistors permits balancing to be done in the amplifier at a position remote from the actual coil installation. The need of large variable capacitors can be eliminated by the use of a fixed capacitor in series with an adjustable resistance. In the actual amplifier the rheostats are replaced with potentiometers. It will be seen in the diagram that the common connection of the pickup coils is grounded and that they are balanced to ground in the control network, on the left leg for resistance, and on the right for reactance. By dividing each potentiometer a coarse and fine control is provided, which is essential if all installation variations are to be compensated without loss of the refinement of adjustment required for operation at high sensitivity.

AMPLIFICATION REQUIRED

Naturally, amplification is required in order to operate an alarm from the minute unbalance voltages which are available. Both to suppress off-frequency interference and to minimize the number of amplifier stages required, the secondary coil system, the matching transformer coupling it to the amplifier, and the amplifier itself are all tuned to the operating frequency.

A voltage gain of about 85,000 is thus obtained, from the signal induced in the secondary coils to the output of a single stage amplifier. For purposes of coarse adjustment and of operating at reduced sensitivity a potentiometer gain control is placed on the amplifier tube grid. The amplifier output operates a small thyratron used as a power relay. Thyratron operation from the steady plate voltage source results in a locking-in alarm requiring acknowledgment from the operator by manipulation of the signal reset button, which breaks the plate supply and permits deionization of the tube. In series with the plate circuit is a relay which indicates that the balance has been upset by lighting two red lamps placed next to the cathode ray tube. These turn the tube screen a bright red, and at the same time the magnetic field from the relay deflects the cathode beam off the screen. This type of signal is much more effective than a separate alarm lamp as the screen is the center of the operator's attention during adjustment and operation.

OPERATING REQUIREMENTS

To permit maintenance of balance and to indicate the presence of small metal objects for which no alarm is desired, some type of continuous indication of degree of unbalance is necessary. Furthermore, operation of the device by technically unskilled personnel requires a type of indicator which will permit the balancing operation to be almost intuitive: that is, simultaneous indication of the direction and amount of the adjustment needed by each of the two balance controls must be given. Indication of the sense of unbalance and separation of the resistive and reactive components requires reference to driving voltage phase. In the past simulanteous indication would have required two instruments, but now a satisfactory solution of the indicator problem is found in the cathode ray oscillograph with grid control. If the driving voltage is applied to the horizontal deflecting plates of the oscillograph tube and the unbalance voltage to the vertical deflecting plates, the figure generally appearing on the screen is an ellipse.

The tilt of the ellipse axis from the horizontal indicates the magnitude of the unbalance voltage component in phase with the driving voltage, while the vertical spread of the ellipse about its center indicates that component in phase quadrature with the driving voltage. The direction of tilt indicates the direction of the cophased unbalance. Furthermore, by supplying the oscillograph control grid with voltage in phase quadrature with the horizontal deflection, one side of the elliptical pattern becomes brighter than the other, and so gives the ellipse a distinctly three dimensional appearance. The direction of the quadrature unbalance is then shown by the tipping of the ellipse backward or forward in its apparent perspective.

With all tuning elements suitably adjusted, motion of the resistive balance control will

(*Continued on page 56*)

Circuit of the Prison Gun Detector

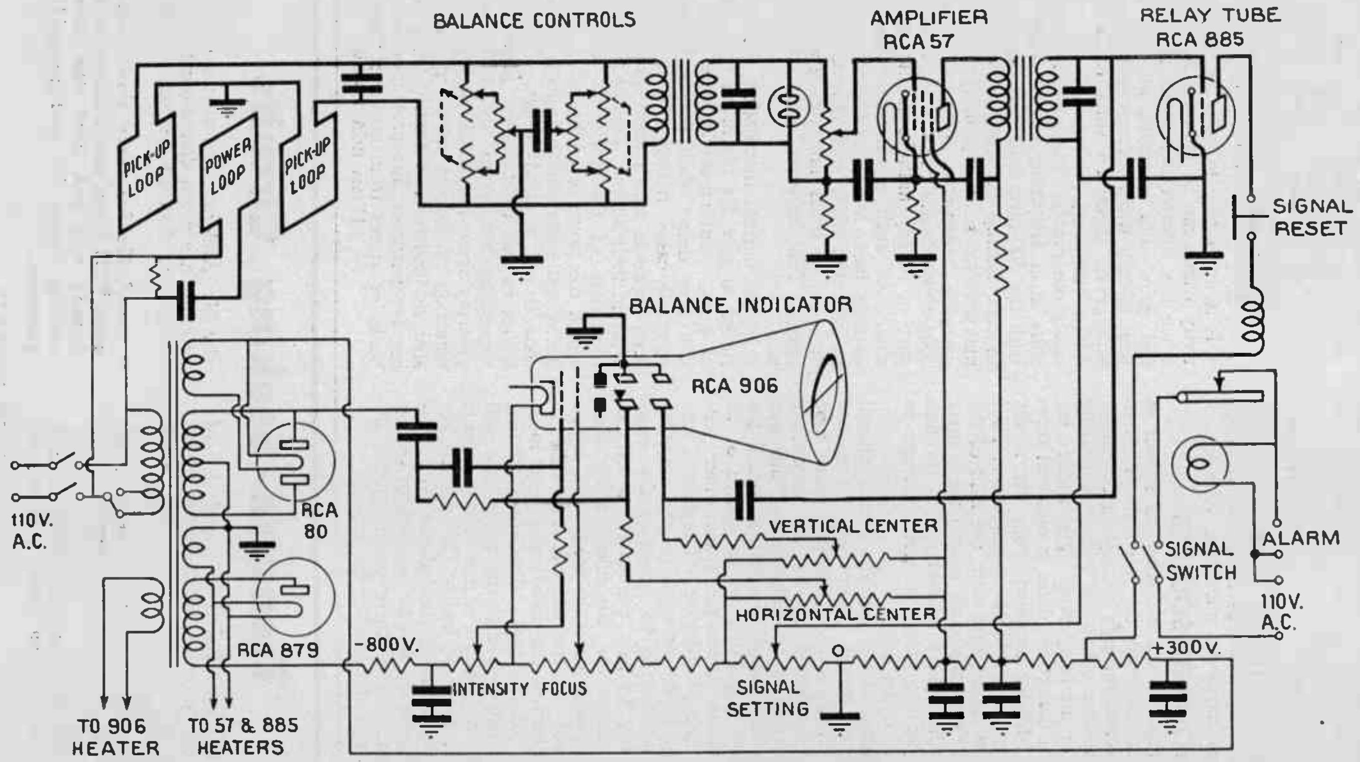


FIG. 6
The circuit diagram of the elctromagnetic metal detector, known generally as a "gun detector." The three loops are at upper left, the cathode ray tube is at center, and the relay for ringing an alarm is at right.

(*Continued from page* 54)

collapse the ellipse to a straight line, while motion of the reactive balance control will tilt this line to a horizontal position, corresponding to a condition of complete balance. The fully phase-sensitive cathode ray balance indicator here described is exceptionally convenient for use with any type of impedance bridge or alternating potential comparator, having as sole disadvantage a lack of inherent discrimination against obscuring of the balance point by harmonic unbalance voltages.

VOLTAGE SOURCES

In the circuit of the amplifier as shown in the schematic diagram the vertical deflection plates are excited through a coupling condenser from the amplifier unbalance voltage appearing on the grid of the relay tube. The voltage for the horizontal deflecting plates is obtained from a resistance divider supplied from the power transformer through a blocking condenser. Thus this excitation is in phase with the field of the driver coil. From the same source the control grid, in parallel with a resistor, is fed through a small capacitor, giving a grid voltage in quadrature with the field.

The remainder of the diagram is conventional except for two details of interest. The first is the use of a voltage limiting glow tube permanently connected across the secondary of the input transformer. The need of this was discovered when a small iron truck passed the loop structure, generated an unbalance of 50 volts, and broke down the transformer secondary and tuning condenser. The second feature is the grid bias network on the amplifier tube. This eliminated the need of the usual cathode resistor by-pass condenser, which becomes very large for 60-cycle amplification. Four potentiometer controls are shown which adjust voltages on the cathode ray tube to center the pattern on the screen, and to set focus and intensity of the spot. The signal setting control is adjusted so that the relay tube will trigger when the pattern on the screen spreads to a height of about ½ inch. This permits readjustment for drifts in the balance with temperature, line voltage and so on, without setting off the alarm. All of these potentiometer adjustments are at the rear of the chassis.

Because of the high degree of electrical symmetry in the device, changes of line voltage have relatively little effect. Slow changes of 15 per cent. are hardly noticeable, while even sudden changes of 30 per cent. affect the balance only moderately. The most serious effect of frequency changes is to produce interlocking of the balance controls because of phase shift in the various resonant circuits.

HIGH SENSITIVITY POSSIBLE

It is interesting to note the very great sensitivity which can be obtained from this detector when low interference levels permit the use of full gain. For example, an oscillograph pattern ⅛ inch wide, corresponding to a deflecting voltage of about 2.6 volts r.m.w.s. or an induced secondary voltage of 30 microvolts is easily observable. Such an induced voltage results at a frequency of 60 cycles per second with the 300-turn coils used, from a difference in flux linking the two pickup coils of 0.027 maxwell r.m.s.; the primary coil of 275 turns carrying 5 amperes produces a flux of about 560,000 maxwells r.m.s. An unbalance of one part in twenty millions is thus easily observable. At such sensitivities masses as small as shoe nails in the protected region begin to be indicated while such objects as a small gun or a set of brass knuckles give a tremendous effect. This, however, is an exceptional condition.

In the normal installation the device is adjusted to give the alarm on the smallest types of guns. Unfortunately, this same sensitivity will also detect such bodies as tobacco tins, spectacle cases, trusses and, in particular, steel arch supports which many people unknowingly wear in their shoes. This fact limits the major usefulness of the device to conditions under which the cause of each alarm can be investigated and some embarassment to innocent persons is not a disadvantage. That is, such a device as this is useful for prevention of arms smuggling into penal institutions or of metal pilfering from industrial plants, as well as for detection of foreign metal in packaged goods such as foodstuffs or textiles; but it is of little use for purposes like protection of commercial banks or stores from armed robbery.

[From RCA Review]

Power Crux of Treasure Quest

Hard Work Needed, No Soft Reclining

By J. E. Anderson

IN the three just preceding issues, September,. October and November, we have discussed several methods for geophysical exploration based on electric or magnetic principles. All were taken from U. S. patent specifications. Hundreds of patents have been issued in this and other countries on devices intended for searching out mineral deposits, but only some of those which appeared to be sound in conception and feasible in application were selected for report. Methods based on seismic principles were omitted because they were outside the field of a magazine devoted to radio subjects.

All the methods disclosed in patent specifications are claimed to be new and novel and workable. They began as early as 1883 and have continued in ever-increasing number. Undoubtedly they were new in the early days, but that they are new now is open to question. Each "new" patented method may have some novel modification or improvement over any preceding method, but no late patent, apparently, is new in its entirety. Many of the methods patented are so nearly alike that the only difference that can be detected is in the phraseology by which the ideas are disclosed.

KEYNOTE IS DISTORTION

All means and methods for geophysical exploration, or treasure-hunting machines, as they are often called, have one thing in common, and this includes seismic methods. This common element is the basic theory upon which they are intended to work. A disturbance of some kind is set up in the ground. This disturbance travels in all directions in the ground, and a "field" results. In a homogeneous earth, or medium, this field is regular and predictible. If, however, the earth is non-homogeneous in the region affected by the original disturbance, the field is distorted.

The amount and direction of this distortion are measured at many points in the explored area, and from the data thus obtained the size and nature of the object causing the distortion are determined, mostly by experience-guided guess work. A skilled worker who thoroughly understands the principles on which his system works, who is able to collect and correlate a mass of accurate data, and who has the necessary equipment, may be able to locate large bodies of ore, metals or minerals. One who is not skilled, or who has little equipment, should not undertake geophysical exploration work.

Certain effects can be obtained with the right instruments. For example, the frequency of an oscillator will be changed, if the design is right, when there is a large body of metal in the field of the oscillating coil. Also, the output of a receiver of suitable design will change as the instrument is brought near a body of metal.

An illustration was given of a device that was used for locating underground pipe lines and electric cables. Such a device is practical, portable and not costly. The difficulty about such explorations is that the free-lance treasure-hunter cannot claim his finds after he has located them. The pipes and cables are private property. The best he can do is to get a contract from the owner to locate and delineate such buried conductors; but that only in cases where the original blue prints have been lost.

The South is the greatest field for the treasure-hunter. Some of those interested might explore a little, either with devices they themselves have built or with commercial devices.

MUCH POWER NEEDED

There are two reasons why so many treasure-hunters are in the South. One is that during the Civil War many rich planters are said to have buried their gold and silver valuables and never lived to recover them. The other is that countless tales of buried pirate treasures circulate in states and islands touching on Gulf and Carribbean waters. Sound methods suitable for prospecting for ore and oil hardly apply to cases of buried chests. Ore bodies and oil pools are hundreds, possibly millions, of times larger than the largest gold and silver hoard ever buried. Small devices are needed for small metal bodies.

All who have tried treasure-hunting with gadgets they have built or bought, and who have admitted doing so, have complained that the gadgets are not sensitive enough. The main reason for lack of sensitivity is that the gadgets are portable. It is simply impossible for a man to carry a big power plant on his back while he is tramping over terrain in which treasure is likely to have been buried.

For a highly sensitive system the transmitter must send a great deal of power into the

(*Continued on following page*)

An Unloaded Detector

And Its Aid to High Performance

By James Millen

General Manager, National Company

Last month the requirements for high signal-to-noise ratio in a modern superheterodyne, using the NC-100 as an example, were discussed. Following is a review of some of the laboratory work that led to the design.—Editor.

THE previous article mentioned that there is a loss of gain and selectivity in the last stage of the i.f. amplifier when diode detectors are used, due to the load which they place on the tuned circuit. On the other hand, by using a combination type, detection and a.v.c. can be accomplished with one tube. Consequently, for a given number of tubes, we thought at first that better overall performance might be obtained by using diodes in spite of their adverse effect on the last i.f. stage. Therefore in planning the first model of the NC-100 it was decided to try out diode detectors, and see what sort of results were obtained.

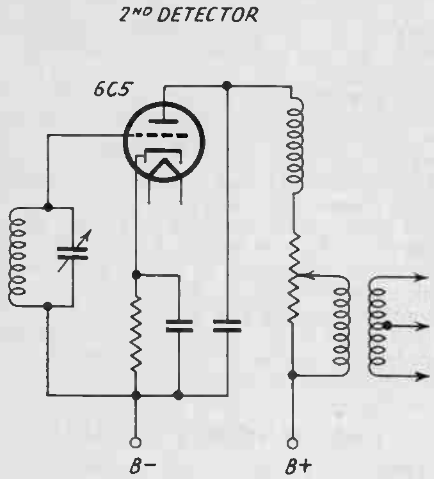


FIG. I
The second detector, with volume control across primary of an audio transformer.

TROUBLE AT FIRST

The first arrangement which we tried made use of a standard i.f. transformer in the last stage. The coils had normal coupling, and both primary and secondary were tuned. This gave pretty good selectivity, all things considered, but the voltage developed by the diodes was very low. Attempts to increase the power supplied to the diodes by the last i.f. tube resulted in overloading the i.f. tube very badly. An extra stage of audio might have been used, thus giving the required signal with low diode output. However, this would have required an extra audio tube as well as an extra d.c. amplifier tube for the a.v.c.

A ray indicator tube such as the 6E5 or 6G5 will enable noting low audio frequencies because the shadow appears and disappears. This use may be applied to zero-beat setting for beat audio oscillators.

Of course, some sets do use just this arrangement, some having as many as three stages of audio. However, since our original idea in using diodes was to save tubes, we decided this plan was out.

The next step was to use a special i.f. transformer, designed for good impedance match between the plate of the last i.f. tube and the diode load. Such transformers are commonly used in broadcast sets today, and have close coupling, a step-down ratio, untuned secondaries, and very poor selectivity. They represent a compromise in that loading is reduced at the expense of selectivity. This compromise is successful to the extent that it enables the diodes to give sufficient voltage, and it is widely

(*Continued on following page*)

(*Continued from preceding page*)

ground, and the receiver must be highly sensitive. Long before the power is great enough to be of much use, the power plant is far beyond the sustaining power of a man; and also long before the power gets great enough, the Government steps in and says you cannot operate without a license. If the Government grants a licence, it will also specify the frequency that must be used in the exploration work. With a small "dowsing" device the explorer will have to indulge in much tramping over the terrain.

A few hopeful treasure-hunters have expressed their desires in the line of a "dowser" quite specifically. It is to be something like a telephoto lens, except that it must be electrical. The operator is to recline in a hammock in the shade of a magnolia tree, sweep the horizon slowly with his directional gadget until a bell rings, and then read upon a dial the very distance in the direction of the pointer where treasure is buried below the surface at a stated depth, and what the type and market value of the treasure is, at yesterday's closing prices. The translation of the expressed desires is rather free, but it breathes the spirit of treasure-hunting.

(*Continued from preceding page*)

used for that reason. When we first tried it out, this scheme seemed pretty good. The control by the delayed a.v.c. was adequate and the tone quality seemed pretty fair at first hearing.

CAUSE OF TROUBLE LOCATED

Unfortunately, the more we listened to the set the worse it seemed to sound. After operating the set at home for a few evenings in competition with other National Receivers we decided that still further changes were in order. It was not hard to tell that the trouble was caused by the delayed a.v.c. circuit. A little thought will show why this is the case.

For perfect audio tone quality, the voltage developed by the diodes should be exactly proportional to the amplitude of the incoming signal. Under favorable conditions diodes come close to meeting this ideal. On the other hand, the requirements of the a.v.c. are quite different. No bias at all should be supplied by the a.v.c. on very weak signals, and yet sufficient bias should be available to hold strong signals to a constant level at the second detector. Control of this sort is obtained by some type of delayed a.v.c. circuit, usually by providing a d.c. voltage that bucks the normal rectifier action of the diode so that no rectified current flows until the carrier reaches a certain amplitude.

INTERMITTENT LOADING

Let us see what happens when an i.f. transformer is supplying power to diodes both for audio and for delayed a.v.c. Suppose a strong signal is being received. The a.v.c. is operating. Every time the carrier level rises above a certain value the diode begins rectifying and supplies power to the a.v.c. circuit. In other words, a sudden load is placed on the last stage of i.f. during *part* of each audio cycle. This intermittent load must be supplied by a high impedance driver, and naturally it tends to level off the peak of each audio cycle. It is very similar to the effect produced in an audio output stage with a low power driving tube when the grids are driven positive.

It is the intermittent nature of the load which causes the trouble of course, and by eliminating the delayed-action feature of the a.v.c. most of the difficulty disappears. This solution is permissible in a broadcast set, but in a communication-type receiver such as the NC-100 it is almost essential to use delayed action to obtain maximum weak-signal response.*

MANUAL CONTROL LOCATION

At this point in our experiments we abandoned diodes completely and used two separate tubes for the audio and a.v.c. This time we were completely successful. The detector circuit is shown in Fig. 1 and is of conventional power detector design. As the grid is negative at all times, no power is drawn from the i.f. amplifier, which therefore works at full efficiency.

The volume control requires some comment. It is obvious that volume must be controlled by varying audio gain when a.v.c. is used. It is also obvious that for best tone quality the detector must operate at full output for all positions of the control. Therefore the volume control can not be in the detector grid circuit. It could be located in the grid circuit of the push-pull output tubes, but it is not convenient to do so because a dual system would be required for the two grids. Practically speaking, this leaves only the detector plate circuit as a suitable location, and here the control has been placed. It was found that when using a 50,000-ohm potentiometer, the detector action was virtually unaffected by the position of the volume control since almost perfect potentiometer action was obtained.

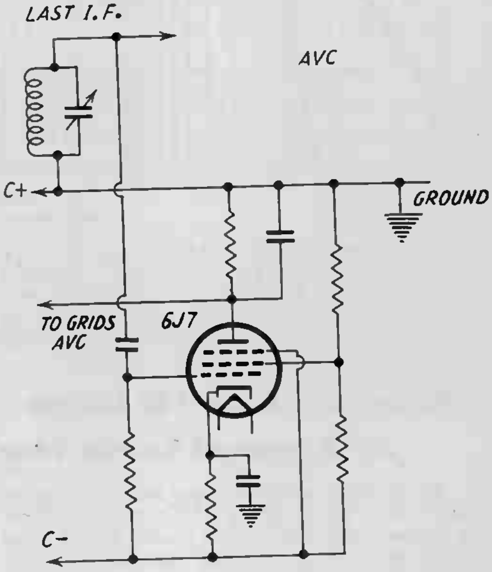


FIG. 2
How the a.v.c. is worked so as to avoid the defects commonly present

The a.v.c. circuit is shown in Fig. 2. Here the 6J7 tube is operated as a vacuum tube voltmeter, but is biased well beyond cutoff to obtain delayed action. The a.v.c. voltage is obtained from the voltage drop across the resistor R3. Since the tube is biased beyond cutoff, the drop across the resistor is nil when weak signals are being received. When the peak signal applied to the grid of the 6J7 becomes greater than the amount of the overbias, plate current begins to flow, a drop appears across the resistor, and control voltage is applied to the grids of the r.f. and i.f. tubes.

FLAT OPERATING CURVE

Due to the very high amplification factor of the 6J7 any further increase in signal results in

(*Continued on following page*)

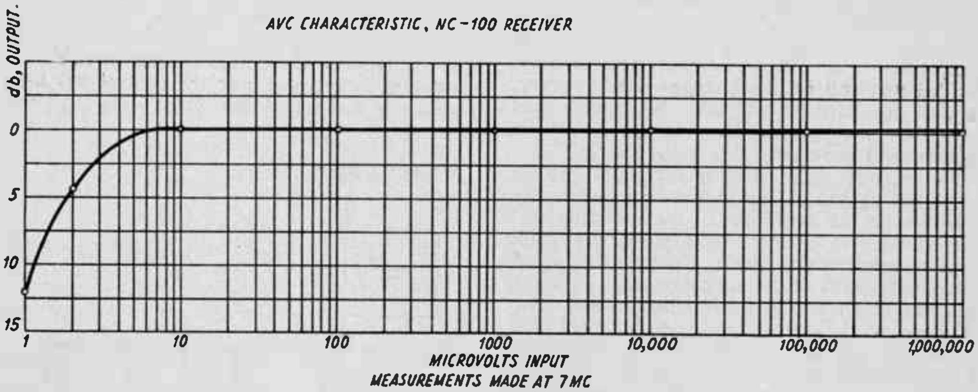
---

*The same principle applies whether single or separate diodes are used for signal rectification and

(*Continued from preceding page*)

a large increase in a.v.c. voltage, so that the control characteristics are excellent. Fig. 3 shows the literal characteristic curve of the a.v.c. circuit, and it will be seen that it approaches very closely to the ideal.

The design of the detector and a.v.c. on the NC-100 has been described in some detail as such circuits are of general interest. Probably most readers of RADIO WORLD have at one time or another been faced with the problem of installing a.v.c. A problem that likewise often confronts the experimenter is the feedback of second harmonic by the second detector. This trouble is often encountered but usually is not difficult to cure once the cause of the difficulty is understood. It is particularly objectionable in receivers equipped with c.w. oscillators, since it shows up as "birdies" that are likely to be mistaken for stations when tuning. When these are encountered, as they were at first in the NC-100, the c.w. oscillator is likely suspected Actually, the trouble is usually in the second detector circuit.



"Radioneer" Coined to Define An Advanced Service Man

At the radio industry show sponsored by the Institute of Radio Service Men at Hotel Pennsylvania, New York City, a new coined word, "Radioneer," was officially presented to the nation.

"Radioneer" is defined as a service man who has proven his technical skill by passing a rigid examination and who also agrees to be govened in his business dealings by a high standard of ethics.

Digest of Patents

The United States Bureau of Mines, Department of the Interior, has published a compilation of patents on geophysical prospecting. The patent-issuing countries covered are United States, England, Canada, Australia, Germany, France and Russia. The report, known as Information Circular 6883, is obtainable from the Bureau, on proof of deservedness, and as long as the limited edition lasts.

BETTER SELECTIVITY with Iron-Core I.F.'s

USERS of our iron-core intermediate-frequency transformers are delighted with the increased selectivity, also the improved gain.

We also have tuner coils, for t.r.f. sets and supers using two-gang to four-gang .000365 mfd. condensers. We do not have tuner coils for 140 mmfd. condensers. Our tuner coils are of the shielded or unshielded types, as preferred. For two-gang sets the unshielded type give better results. For three- or four-gang sets the shielded type are necessary. Either type obtainable in high-gain or low-gain models.

Iron-core, doubly-tuned i.f. transformers. 175, 456 or 465 kc (specify which)......$1.15

High-gain r.f. coils, for .000365 mfd., for two-gang t.r.f. set, unshielded. 90¢ a pair.

High-gain r.f. coils for three-gang t.r.f. set, shielded..................$1.80 for three.

Low-gain r.f. coils for four-gang t.r.f. set, shielded ....$2.40 for four.

Local oscillator coil, shielded, for 175. 456 or 465 kc.......................................60¢

Local oscillator coil, unshielded, 456 or 465 kc. only ....45¢

Set of matched shielded coils for three-gang super (specify i.f.)..................$1.80

Set of matched shielded coils for four-gang super (specify i.f.)..................$2.40

8 millihenry honeycomb r.f. choke.....40¢

One-to-one transformer, two 8 millihenry windings loosely-coupled, in shield......$1.00

Coils are on hand for all circuits using .000365 mmfd. for tuning. State your requirements.

Padding condenser for 465 or 456 kc....50¢

Padding condenser for 175 kc..........55¢

All the above prices are postpaid.

SEND FOR FREE CIRCUIT DIAGRAMS, T.R.F. AND SUPERS

RADIO DESIGN CO.

Dept. R-1236

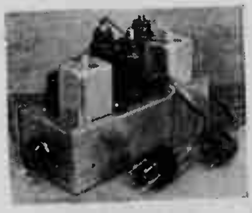
1353 Sterling Place Brooklyn, N. Y.

WALLY'S

Largest dealer service in the city.
Cracker-jacks on tough installations and motor noise elimination.
(Authorized All Makes)
AUTOMOTIVE AND MARINE SPECIALISTS
HUDSON TERMINAL GARAGE BLDG.
61 Dey Street, 1 block south Fulton St., New York City
WOrth 2-9080 WOrth 2-3131

Noise Silencer Adapters

are a great help on reducing natural static too. LEEDS "QUIET CAN" and "SILENT CAN" also provide freedom from ignition noises and afford an ideal arrangement for push to talk phone and break-in CW.



LEEDS "Quiet Can" for receivers with 2 IF stages; complete with tubes and instruction $7.95

LEEDS "Silent Can" illustrated herewith for receivers with 1 IF stage; complete with tubes and instruction. $9.95

LEEDS RADIO COMPANY

45 VESEY STREET N. Y. CITY

THREE TUBE SHORT WAVE RADIO only $3.25

(Less tubes, phones, unwired)

A real, powerful, 3-tube radio set capable of bringing in amateurs, broadcast stations, police calls, and foreign as well as domestic short wave stations with excellent volume under fair conditions.

Operates entirely from your AC or DC house current. Range 10-600 meters. Extremely simple to build and operate. Furnished complete with coil and detailed instructions.

2-TUBE BATTERY KIT..........$7.00
Operates from inexpensive dry batteries.

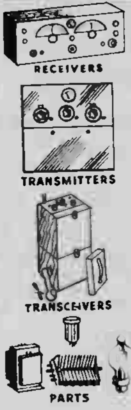
3-TUBE BATTERY KIT..........$2.95
Operates from inexpensive dry batteries.

Kits wired, extra. 75c. Tubes, extra, 50c each. Cannon ball double headphones, extra, $1.35.

FREE: Large, illustrated catalogue

EILEN RADIO LABORATORIES

Dept. RW-1, 136 Liberty Street
New York, N. Y.



"What's New In Amateur Equipment?"
You'll find the answer in your 1937 ALLIED Catalog. The special Amateur Section is packed with the latest in Short Wave receivers, transmitters, transceivers and Ham gear—at the lowest prices. Read all about the new National "One-Ten" and NC-100; Hallicrafters Sky-Buddy, Sky-Chief, and Ultra-Sky-Rider; Sargent Models 10AA, 11AA, and 11UA; RCA ACR-136, Hammarlund Super-Pro and many others. See pages 125-6-7 for dozens of Build-Your-Own kits, including the All-Star X'mitter, Knight Metal Tube Super Gainer, 5 Meter Transceiver, DX'er, etc. Our prices are the lowest—our quality the highest—our service the fastest—you save on every purchase when you order from ALLIED!

Radio's MOST COMPLETE Supply Guide
The big new 1937 ALLIED Catalog also lists over 10,000 exact duplicate and replacement parts; 38 sensational new Knight Radios—5 to 19 tubes; latest PA equipment; newest Test Instruments; Rurlpower units and Wind-chargers; tools, books, etc. If you haven't a copy of this great book send coupon now!

ALLIED RADIO

833 W. Jackson Blvd., Dept. 16-M
Chicago, Ill.

Send your free 152-page 1937 Catalog.

Name ....

Address ....

City...

CLASSIFIED ADVERTISEMENTS

7 cents a word. $1.00 minimum.

AMATEUR RADIO LICENSES. Resident and correspondence courses. Every graduate a licensed operator. New York Wireless School, 1123 Broadway, New York.

STATIONERY—$1.25 POSTPAID, brings you 125, 5½ x 8½ sheets, 100 envelopes, printed with your name and address or monogram, on beautiful white bond paper, in rich blue ink. West of Mississippi, ten cents additional. Port Stationery Company, Dept. A, Port Chester, New York.

PERSONAL PRINTED SELF SEAL ENVELOPES. 50 printed to your order for 35 cents. Morey's Press, 87 Somerset St., Springfield, Mass.

POETS INVITED TO CONTRIBUTE
to important new anthology of Poetry—of special interest to residents in Canada (or America). Particulars free from Publishers: Arthur Stockwell, Ltd., 29 Ludgate Hill, London (England). MSS of all types also required. No reading fees. Current list on application.

ATTENTION! SERVICEMEN: A catalogue containing 40 most popular Majestic Schematic Diagrams — 50c postpaid. Diagrams for any make receiver — 40c. Address: Waxman Sales, 1574 - 56th St., Brooklyn, N. Y. Dept. K.

FOR MODERN RADIO Reception. Use your old aerial. Make your own All-Wave DX system. Simple plan and instructions, 20 cents. OCEANIC ALL-WAVE SYSTEM, 140 West 42nd, New York, N. Y.

SPECIAL 2-FOR-1 OFFER

RADIO WORLD

Radio World is $2.50 a year (12 issues), 25c. per copy. Canada and foreign, $3.00 yearly. Offers of Radio World and other worthwhile publications for one full year on each (NET):

☐ RADIO WORLD and SHORT-WAVE CRAFT, $3.50.

☐ RADIO WORLD and POPULAR SCIENCE MONTHLY, $3.50.

☐ RADIO WORLD and RADIO-CRAFT (12 issues), $3.50.

☐ RADIO WORLD and RADIO INDEX (monthly, 10 issues). stations, programs, etc., $3.50.

☐ RADIO WORLD and SERVICE (monthly), $3.50.

☐ RADIO WORLD and EVERYDAY SCIENCE AND MECHANICS (monthly), $3.50.

☐ RADIO WORLD and BOYS' LIFE (monthly, 12 issues), $3.50.

☐ RADIO WORLD and MOTION PICTURE MAGAZINE (monthly), $3.50.

☐ RADIO WORLD and TRUE STORY (monthly), $3.00.

☐ RADIO WORLD and LIBERTY (weekly), $3.00, U. S. only.

Select any one of these magazines and get for an entire year by sending in a year's subscription for RADIO WORLD at the regular price, $2.50, plus a small additional amount, per quotations above. (Add $1.50 for extra foreign or Canadian postage for both publications.)

Name ....

Address ....

City and State.......................................

☐ If renewing an existing or expiring subscription for RADIO WORLD, put cross in square.

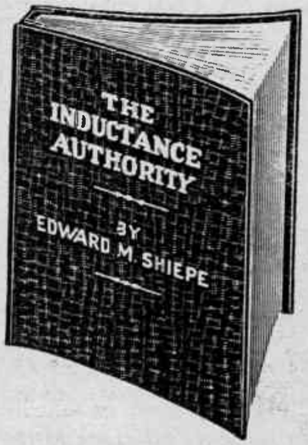
☐ If renewing an existing or expiring subscription for other magazines, put cross in square.

Special Trial Offer for Radio World only: $1.00 for 5 months, postpaid. Mail order with remittance to Radio World Office. NET.

The Remedy for...

ANNOYING COIL PROBLEMS!

WINDING solenoid coils for radio frequencies requires knowledge of the number of turns of any selected type of wire on any sensible diameter to attain an inductance suitable for the tuning condenser and lowest frequency. Hence, with capacity and frequency known, there are two unknowns: (1), the required inductance; (2), the number of turns to establish that inductance. The answers are obtained without computation by use of "The Inductance Authority," by Edward M. Shiepe, and an 18 x 20" supplement. On the large supplement are plotted the "curves" of frequency, capacity and inductance in straight lines, so for a desired low frequency and known capacity the unknown inductance is solved by mere inspection. The number of turns for attainment of that inductance, for all popular tubing diameters and all generally used wire diameters and wire insulations, is read from the inductance-turns charts which are in the bound volume. Coil and set manufacturers, as well as home and shop experimenters, students and teachers freely use this book. Accuracy is 1%. The only book of its kind in the world.



Order Cat. INA (price includes bound volume and supplement) postpaid anywhere on earth **$2.00**

The supplement chart is obtainable separately, CAT. SIA @ 25c postpaid.

Or send $5.00 for a two-year subscription for RADIO WORLD, regular rate, and this valuable book and supplement will be sent FREE and postpaid. Order Cat. PR-IAC.

Those specially interested in coil data for the standard broadcast band will find extremely valuable a straight-line chart of frequency, capacity and inductance, 500 to 2,500 kc very closely plotted, 2,500 to 12,000 less closely, published in the October, 1936, issue of RADIO WORLD. Order Cat. 695. 25c per copy (extra).

BOOK DEPARTMENT

RADIO WORLD

145 West 45th Street, New York City

MAILING LISTS

GET OUR FREE
REFERENCE
BOOK *and*
MAILING
LIST CATALOG
FREE

Gives counts and prices on accurate guaranteed mailing lists of all classes of business enterprises in the U. S. Wholesalers—Retailers—Manufacturers by classification and state. Also hundreds of selections of individuals such as professional men, auto owners, income lists, etc.

Write today for your copy

R. L. POLK & CO.
Polk Bldg.—Detroit, Mich.
Branches in Principal Cities
World's Largest City Directory Publishers
Mailing List Compilers. Business Statistics. Producers of Direct Mail Advertising.

120 DB GAIN!
30 WATTS!

Harvey Amplifier Kit (Less Tubes) $19.40

HERE is a real buy! Our standard 137 Amplifier in kit form, complete, less only tubes, at a smashingly low price for such a quality P.A. system, using six tubes, with 6L6-G push-pull output! We are leaders in the amplifier business!

Here's what you get—order all the parts or any of them separately—and enjoy our fast service:

1 Chassis, $1.50; 1 Power Trans., $4.80; 1 Output, $1.80; 1 Dual Cond., 90c.; 3—8 Mfd. Cond., $1.80; 1—200 ohm 10 W., 20c.; 1—25 Mfd., 25c.; 2—Chokes, $3.50; 4.1 Cond., 60c.; 15 Res. 1 W., $1.50; 6000 10 W., 20c.; 1—Vol. Control., 40c.; 6 Sockets, 60c.; 1 Bias Cell., 30c.; 1 3.5 Mfd. Cond., $1.05; Total, $19.40.

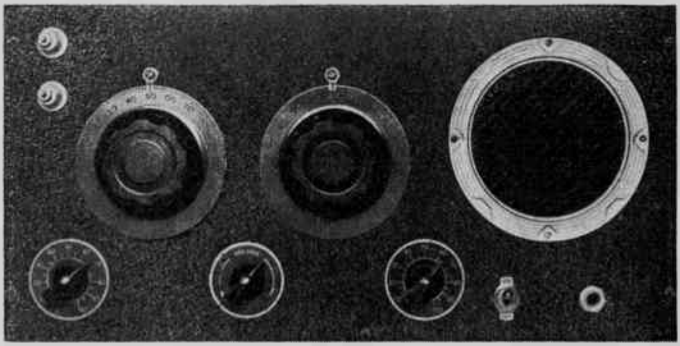
HARVEY RADIO CO.
NEW YORK
Harvey E. Sampson, President
103 WEST 43RD STREET
NEW YORK, N. Y.
Send for Parts Circular 1236-W

AN OUTSTANDING ACHIEVEMENT!

RACO AC-4

Communication
Receiver
2½-555 Meters

An All-Purpose Receiver
That Defies Competition



THE MOST REMARKABLE RADIO VALUE WE HAVE EVER OFFERED

And when we say communication receiver we MEAN it. The AC-4 is built to the highest amateur specifications for serious communication and long distance reception under all conditions. Isolantite insulated high frequency and band-spread tuning condenser; continuous, all electrical, band-spread; perfect regeneration stability; super-regeneration below 15 meters; and a host of other features. The 20 meter band, for instance, covers 100 degrees on the big 3½" German silver band-spread dial with NO hand capacity effect. You will be amazed at the way the AC-4 separates the crowded foreign stations on the short wave bands.

BUILT-IN A.C. POWER PACK

The AC-4 uses three of the powerful new Sylvania 6J5G tubes as electron coupled detector and two stage audio, plus an 80 rectifier with built-in high voltage supply which is really quiet.

Separate panel controls for antenna coupling, audio volume and regeneration. A standby switch is provided and also an earphone jack which cuts out the speaker.

RACO AC-4; Complete Kit of parts, unwired, less only cabinet and tubes	$10.75
Crystaline finished metal cabinet	1.25
Kit of four picked Sylvania tubes	2.05
Wiring and testing	2.50

SPECIAL PRICE ON COMPLETE RACO AC-4; wired, tested and ready to operate from any 110 volt A.C. line........................ $15.85

RADIO CONSTRUCTORS LABORATORIES

Dept. RA-1, 136 Liberty St.
New York, N. Y.

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACT OF MARCH 3, 1933,

Of Radio World, published monthly at New York, N. Y., for October, 1936.

State of New York, } ss.:
County of New York, }

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Roland Burke Hennessy, who, having been duly sworn according to law, deposes and says that he is the Editor of the Radio World, and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of Aug. 24, 1912, embodied in Section 537, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor and business managers are: Publisher, Hennessy Radio Publications Corp., 145 West 45th St., N. Y. C. Editor, Roland Burke Hennessy, 145 West 45th St., N. Y. C. Managing Editor, Herman Bernard, 145 West 45th St., N. Y. C. Business Manager, Roland Burke Hennessy, 145 West 45th St., N. Y. C.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of the stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.) Hennessy Radio Publications Corp., 145 West 45th St., N. Y. C. Roland Burke Hennessy, 145 West 45th St., N. Y. C.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.) None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company, but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

5. That the average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers, during the months preceding the date shown above is.....:....... monthly magazine. (This information is required from daily publications only.)

ROLAND BURKE HENNESSY
(Signature of Circulation Manager.)

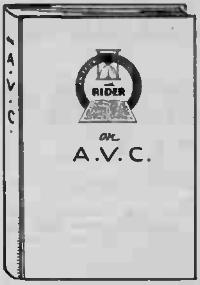
Sworn to and subscribed before me this 1st day of October, 1936.

(Seal.) ELIZABETH ANSBACHER.

Notary Public, New York Co., No. 68. Reg. 6A144. My commission expires March 30, 1939.

Note.—This statement must be made in duplicate and both copies delivered by the publisher to the postmaster, who shall send one copy to the Third Assistant Postmaster General (Division of Classification), Washington, D. C., and retain the other in the files of the post office. The publisher must publish a copy of this statement in the second issue printed next after its filing.

"AN HOUR A DAY WITH RIDER"



John F. Rider has written a series of pocket-sized books, 60c each, with the idea readers will spend an hour a day reading and studying them, and thus acquiring a full servicing knowledge. Latest of these is devoted to automatic volume control (a.v.c.). The subject is fully covered. 64 pages. Well illustrated. Order Cat. RAVC postpaid @ 60c.

"ALTERNATING CURRENTS"

"Alternating Currents in Radio Receivers," Hour-a-Day, is a comprehensive book covering the basic functions of the various components of a radio receiver, what each unit does and how it works. Various types of parallel and series resonant circuits, different kinds of coupling, inductance, reactance, impedance, and how these electrical phenomena are employed in radio practice, are fully explained. 80 pages. Order Cat. RAC, postpaid, @ 60c.

A clear explanation of what happens when a circuit is tuned to resonance. All types of circuits described and how and why they work. How these circuits should be aligned so that maximum efficiency is obtained. Knowledge of the latest high-fidelity i-f. amplifiers is becoming more and more necessary and "Resonance and Alignment" tells what you should know about all this. 64 pages. Order Cat. RRA, postpaid, @ 60c.

"D. C. VOLTAGE DISTRIBUTION"

Every receiver contains some sort of d.c. distribution system supplying the d.c. voltages from the power unit to the elements of the tubes. The many different forms these systems take are thoroughly described in Rider's "D.C. Voltage Distribution," which explains networks from the simplest to the most complicated. The calculations of the value of the resistors and their wattage ratings are more clearly described than ever before, in this brand new combination of theory and practice. 64 pages. Order Cat. RDCVD, postpaid, @ 60c.

[Above four "Hour-a-Day" books are all of the series published to date. All have hard covers. The order of their publication is No. 1 A.C.; No. 2, Resonance; No. 3, D.C.; No. 4, A.V.C.]

RIDER'S MANUALS

Vol. VII—(new) Rider's Volume VII has 1600 pages! This is the biggest and best Manual that has ever been published. In Volume VII the number of manufacturers has been increased and therefore the size of the book was increased. The greatest collection of servicing data ever gathered and not only from the large manufacturers, but the smaller ones as well. Not only 1936-37 sets, but many old timers. 100-page Index $10.00

Vol. VI—Data on sets produced up to October, 1935—the start of the metal tube era—are contained in this Manual. Double-Spread pages are used for the more complicated receivers. 1240 pages, $7.50

Vol. V—Sets manufactured up to October, 1934—and older sets, too—are covered in this volume. Electrical and mechanical data are given so that everything is where you want it. 1,200 pages........ $7.50

Vol. IV—In this volume will be found information on receivers manufactured up to March, 1934. 1,060 pages $7.50

Vol. III—Sets released from the middle of 1932 to June, 1933 are presented in this volume. 1,070 pages $7.50

Vol. II—Data are here contained on sets manufactured between early 1931 and the middle of 1932. Many sets unavailable when Vol. I was published will be found in Vol. II. 800 pages............ $6.50

Vol. I—This volume contains information on the old timers—from 1919 up to 1931—and there are still many of these in use today. 1,000 pages.... $7.50

[Order Rider Manuals by volume numbers as listed above. Remit with order. Books will be sent postpaid.]

Radio World, 145 W. 45 St., N. Y. City

YOUR JOBBER SELLS

AMPERITE

VELOCITY MICROPHONES

Watch for Sensational Announcement!

$1.00 a month

Is all you need to pay for

LIFE INSURANCE

$1194.00 of insurance at age 21; $813.00 at 35. Other ages in proportion in this Old Line Legal Reserve Company that sells without agents and gives the saving to its policy holders. Postal has paid out $43,000,000 in 31 successful years. It has millions in assets and reserves. Just write a card today with your name, address and exact date of birth and you will get full details and rates for your age by return mail. Insurance is vital: Act promptly while rates are low.

POSTAL LIFE INSURANCE COMPANY
Dept. RD-195—511 Fifth Avenue, New York

You need . . . these 2 books

PRINCIPLES of PUBLIC ADDRESS SYSTEMS

A practical handbook, full of useful information, fully illustrated, written by M. N. Beitman, an engineer and noted authority on audio amplifiers.

Considers in detail various microphones, radio and phonograph inputs, acoustic feedback, mixing and volume controls, use of vacuum tubes, interstage coupling, power amplifiers, output coupling, loud speaker placement, the decibel, P.A. measurements, power level, and other points of importance, including actual circuit diagrams of tested P.A. systems.

MATHEMATICS of Radio Servicing

Introduces and explains the use of arithmetic and elementary algebra in connection with units, color code, meter scales, Ohm's Law, alternating currents, ohmmeter testing, wattage rating, series and parallel connections, capacity, inductance, mixed circuits, vacuum tubes, curves, the decibel, etc., etc., and has numerous examples.

Plainly written and easy to understand. Only useful data included. M. N. Beitman, author. Size, 8½ x 11 in.

Price, 50c each book.

SUPREME PUBLICATIONS
3727 West 13th St., Chicago, Illinois

METAL CHASSIS

We can supply chassis for any make receiver, experimental or otherwise.

Inquiries should be accompanied with sketch and complete details enabling us to give quick service as to prices and delivery.

Dept. R.W. 126

KORROL MFG. CO., Inc.
232 Greenwich St. New York City

OUTSTANDING VALUE!

Model T-37 SIGNAL GENERATOR

The fastest selling Signal Generator on the market. You can't help but recommend it. Hundreds sold since its introduction three months ago.

Complete . . only **$12.40**

- 110 Volts A.C. or D.C. 110 kc. — 22 megacycles all on fundamentals.
- Dial is direct reading in frequencies.
- R.F. output may be taken from a high impedance or a low impedence post, in with attenuation present for either.
- Separate audio output at 2 amplitude levels, so that tone may be used for checking public address systems, audio amplifiers in receivers, and speech amplifiers in transmitters.
- Two extra posts on front panel enables leakage tests. Condensers may be checked for leakage, so may tubes, and other normally high resistance currents, otherwise difficult to test.

Model T-37 All-Wave Signal Generator, wired, in shielded cabinet with carrying handle and calibrated, tested; complete with 3 tubes, instructions, (shpg. weight 7 lbs.) $12.40

PRECISION

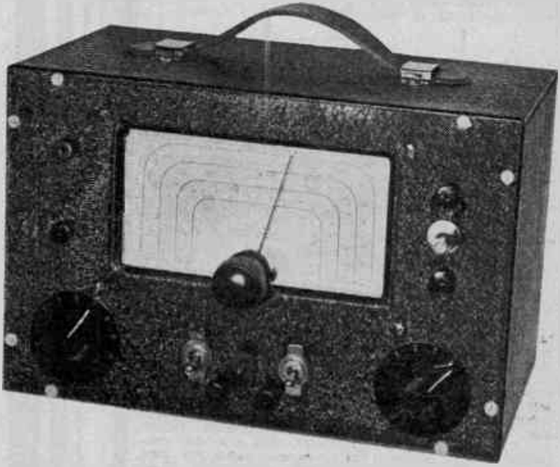
CONDENSER ANALYZER

Output Meter – Leakage Tester

Complete with 2 tubes **$7.40**

AN AMAZING PRICE on a new instrument that *every* service man and home experimenter needs. Not an approximate meter reading but a true capacity bridge that is

DIRECT READING up to 16 mf.



Tells Everything You Want To Know About a Condenser

- Is it shorted or open circuited?
- Does it leak and how badly?
- What is its capacity?

THEN throw a switch and you have a sensitive output meter with shunt voltage adjustment for use with your oscillator when lining up receivers.

Three instruments that are indispensable to every serviceman; combined in one small portable case and operating directly from the 110 volt A.C. line.

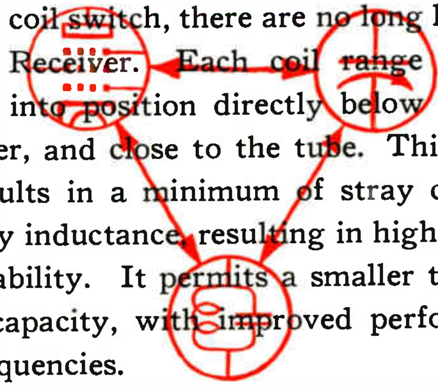
Model 40 Capacity Analyzer, in shielded cabinet with carrying handle, wired, calibrated and tested; complete with 2 tubes $7.40. (Shipping Weight 7 lbs.)

SUPERIOR INSTRUMENTS COMPANY

Dept. 102, 139 Cedar Street
New York, N. Y.

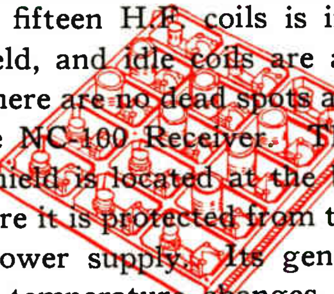
NC-100 RECEIVER

1. PERMITS COMPACT WIRING



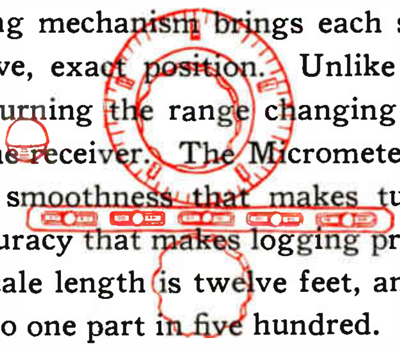
Unlike a coil switch, there are no long leads in the NC-100 Receiver. Each coil range in turn is brought into position directly below the tuning condenser, and close to the tube. This compactness results in a minimum of stray capacitance and stray inductance, resulting in high gain without instability. It permits a smaller tuning condenser capacity, with improved performance at high frequencies.

2. ISOLATES IDLE COILS



Each of the fifteen H.F. coils is in its own individual shield, and idle coils are always out of the way. There are no dead spots and absorption losses in the NC-100 Receiver. The heavy cast aluminum shield is located at the bottom of the receiver where it is protected from the heat of the tubes and power supply. Its generous proportions retard temperature changes.

3. ASSURES PRECISE TUNING



The shifting mechanism brings each set of coils into positive, exact position. Unlike many coil switches, turning the range changing knob does not tune the receiver. The Micrometer Dial contributes a smoothness that makes tuning easy, and an accuracy that makes logging precise. The effective scale length is twelve feet, and readings are direct to one part in five hundred.

NATIONAL COMPANY, INC., MALDEN, MASS.

RANGER EXAMINER

D. C. POCKET VOLT-OHM-MILLIAMMETER

★

MOLDED CASE
3" x 6" x 2" (Approximately)

★

SELECTOR SWITCH
FOR ALL RANGES

★

BATTERY, TEST LEADS AND
ACCESSORIES INCLUDED

★

ACCURACY TO 2%

MODEL 735

A PRECISION INSTRUMENT AT A SENSATIONAL PRICE

DEALER PRICE **$10.80**

Model 735 has a Triplett D'Arsonval type precision instrument with easily readable scales. Ranges are 15-150-750 volts; 1.5-15-150 M.A.; ½-1000 low ohms; 0-100,000 high ohms at 1.5 volts. Provisions for external batteries for higher resistance measurements. Has selector-switch for all ranges and individual zero adjustment for resistance measurements.

Sturdy molded black case, 3 1/16" x 5⅞" x 2⅛" high. Attractive silver and black panel. Battery and test leads with alligator clips are included. Dealer Net Price Complete $10.80.

RANGER EXAMINER

READRITE METER WORKS
1227 College St., Bluffton, Ohio.

Please send me more information on Model 735 Volt-Ohm-Milliammeter. I am also interested in............
....
Name ....
Address ....
City .... State ....