We commend this book of Laboratory Information Sheets to the attention of all radio fans who desire authentic technical data presented to them in a clear, concise and convenient form.

The experimenter and technical radio man will find in it a wide range of radio information. These Radio Data Sheets have been compiled by the Technical Staff of Radio Broadcast Laboratory.

Price, $1.00
The NEW Scott Shield Grid 9
Radio's Most Powerful Receiver!

For those who want radio reception at its highest development, this is the set to build! Even more powerful than the preceding Scott receivers that established four world's records for DX reception. More selective. More superbly toned! In range, the new Scott Shield Grid Nine is practically unlimited—the only range limit being the atmospheric noise level.

New Shield Grid Tubes in improved circuit
The new Scott uses shield grid tubes in an improved circuit with new power pack and amplifier. Through the greater efficiency of the new tubes and circuit, many times the amplification obtainable with the ordinary circuit using 201-A tubes is secured. The Scott Power Pack and Amplifier makes it possible to obtain enormous volume—yet so completely is this volume under control that the simple turning of one knob covers the entire range from merest whisper to full auditorium strength.

Perfected matching of parts
Not only is the Scott Receiver new in design, but it represents new ideals in accuracy of radio building. All parts are designed especially for this set and are matched with absolute precision. The extreme care taken in testing and matching the transformers is one of the reasons why the new Scott out-performs in competitive DX tests.

Maximum efficiency from highest to lowest wavelengths
Transformers as well as tubes are perfectly shielded in the new Scott. The efficiency of the R.F. stage ahead of the first detector is increased through the use of a special Seletone Two-Gang Condenser and regeneration in the first detector. The Two-Gang Condenser matches the impedances of the antenna and R.F. coils so perfectly that they line up throughout the entire scale, affording range-edge selectivity with maximum amplification all the way from the lowest to the highest wave lengths.

One spot reception
All stations come in at one point only on the dial in this “one spot” super. A further improvement is evidenced in the fact that both dials track practically together—making tuning particularly easy.

Costs little to operate
The Scott Shield Grid Nine can be economically operated with dry batteries if desired and will give ample volume for the average home. The eight tubes incorporated in the receiver draw only 29 ma's. Maximum volume is obtained by the use of the Scott Power Pack and Amplifier, incorporating the ninth tube for the second stage of audio. This is the latest 250 power tube, a new radio development that gives tremendous volume with perfect tone quality.

Build the new Scott in four hours
RESULTS GUARANTEED

New and highly developed as the Scott receiver is, anyone can build it—easily—and in four hours! Panel and sub-panel are drilled to receive each part; and the shielded grid amplifier unit comes fully tested and wired, ready for hook-up into the circuit. No adjustments whatever are needed. No possible chance for errors in the assembly.

We positively guarantee that you will get the same results with the Scott Shield Grid Nine that we obtain from our laboratory models.

FREE Circuit Diagram and Particulars

Write at once for particulars! Get the facts about this amazing new world's record set—its low cost—unlimited range—tremendous power—to kilobase selectivity. Build this set now and enjoy radio at its best! FREE circuit diagram. Also copies of 6000 and 9000 mile reports in verifications. Write today, NOW!

SET BUILDERS! We offer an unusual plan that will triple your custom set business. Ask your jobber. Or write us direct.

— — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — —

SCOTT TRANSFORMER COMPANY
4456 Ravenswood Ave. Chicago, Ill.

Please send me FREE circuit diagram, records, and full particulars of the new Scott Shield Grid Nine.

( ) I am interested in your proposition to professional set builders.

Name                                         Street

Town                                          State

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The
Radio Broadcast

LABORATORY
INFORMATION SHEETS

Prepared by
HOWARD E. RHODES
Radio Broadcast Laboratory

Numbers 1-190
With Index On Page 70

First Edition

Doubleday, Doran & Company, Inc.
Garden City, New York

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I Will Train You at Home to Fill a Big-Pay Radio Job

If you are earning a penny less than $50 a week, send for my book of information on the opportunities in Radio. It’s FREE. Clip the coupon NOW. A flood of gold is pouring into this new business, creating hundreds of big-pay jobs. Why go along at $25, $50 or $250 a week when the good jobs in Radio pay $50, $75 and up to $250 a week? My book "Rich Rewards in Radio" gives full information on these big jobs and explains how you can quickly become a Radio Expert through my easy, practical home-study training.

Salaries of $50 to $250 a week not unusual

Get into this live-wire profession of quick success. Radio needs trained men. The amazing growth of the Radio business has astounded the world. In a few short years three hundred thousand jobs have been created.

And the biggest growth of Radio is still to come. That's why salaries of $50 to $250 a week are not unusual. Radio simply hasn’t got nearly the number of thoroughly trained men it needs. Study Radio and after only a short time land yourself a REAL job with a REAL future.

You Can Learn Quickly and Easily in Spare Time

Hundreds of N. R. I. trained men are today making big money—holding down big jobs—in the Radio field. Men just like you—they're only advantage is training. You, too, can become a Radio Expert just as they did by our new practical methods. Our tested, class training makes it easy for you to learn. You can stay home, hold your job, and learn quickly in your spare time. Lack of education or experience is no drawback. You can read and write. That's enough.

Many Earn $15, $20, $30 Weekly on the Side While Learning

My Radio course is the famous course "that pays for itself." I teach you to begin making money almost the day you enroll. My new practical method makes it possible for you.

RADIO OUTPUTS OF Radio trainees with my course. You are taught to build practically every type of receiving sets known. M. E. Battaglia, 445 73rd Street, Brooklyn, N. Y., writes: "I made $700 while studying." Erle Cummings, 16 Webster St., Newton, Mass., "I made $350 in one month." G. W. Page, 1007 21st Ave., S. Nashville, Tenn., "I picked up $65 in my spare time while studying.

Your Money Back if Not Satisfied

I'll give you just the training you need to get into the Radio business. Your course fits you for all lines—manufacturing, selling, servicing sets, in business for yourself, operating on board ship or in a broadcasting station—and many others. I back up my training with a signed agreement to refund every penny of your money if, after completion, you are not satisfied with the course I give you.

ACT NOW—64-page Book is FREE

Send for this big book of Radio information. It won't cost you a penny. It has put hundreds of fellows on the road to bigger pay and success. Get it sent to you IMMEDIATELY. See what Radio has to offer you, and how my Employment Department helps you get into it after you graduate. Or tear out the coupon and mail it RIGHT NOW.

J. E. SMITH, President
Dept. 80
National Radio Institute
Washington, D. C.

You can build 100 circuits with the six big outfits of Radio parts I give you

3 of the 100 you can build

Find out quick about this practical way to big pay

Mail This FREE COUPON Today

J. E. SMITH, President
Dept. 80, National Radio Institute, Washington, D. C.

Dear Mr. Smith: Kindly send me over big book "Rich Rewards in Radio," giving information on the big-money opportunities in Radio and your practical method of teaching with no obligation whatever.

Name __________
Address __________
City __________ State __________
Occupation __________
No. 1

Radio Broadcast Laboratory Information Sheet

Regeneration

Methods of Control

When radio waves of the frequency to which the antenna circuit is tuned are received, the high frequency currents flowing in the coil produce high frequency variations in the grid potential which, in turn, produce high frequency currents (considerably greater energy) in the plate circuit. If we could "feedback" some of this plate energy to increase the original potential applied to the grid, it might help to increase the original potential applied to the grid. This can be done in several ways. A very common method is shown in A.

No. 2

Radio Broadcast Laboratory Information Sheet

Factors Governing Radio Receiving

How They Affect Distance

There are three main factors governing the distance that can be satisfactorily covered between a given transmitting station and a given receiving set. These can be stated as follows:

1. The receiving station's location in the earth's electromagnetic field. This is determined by the receiving antenna and the atmosphere through which the waves travel.

2. The distance from the transmitting station to the receiving antenna. This is determined by the size of the transmitting antenna and the distance between the transmitting and receiving stations.

3. The distance from the receiving antenna to the ground. This is determined by the height of the receiving antenna and the topography of the ground.

No. 3

Radio Broadcast Laboratory Information Sheet

The Browning-Drake Receiver

On Sheet No. 4 is shown a diagram of the Browning-Drake receiver, which, in its improved form, was fully described by Glenn H. Browning, one of the designers, in the December, 1925, Radio Broadcast. The first article appeared in this magazine for December, 1924. Three stages of impendence-coupled audio amplifiers are employed in this circuit. The constants of the coil circuit as shown, are as follows:

- C—.0005 mfd. variable condenser.
- C—.00025 mfd. fixed condenser.
- C—.01 to .025 mfd. fixed condenser.
- L—.025 mfd. fixed condenser.
- L—.05 turns No. 20 d.c. wire on a 3 inches diameter form to make a center tap.
- L—.75 turns No. 20 d.c. wire on a 3-inch form to make a center tap.
- L—.25 turns No. 20 d.c. wire wound on a .5 inch form to in grid of secondary (L). 1—.10 mfd choke coils.
- N—Neutralizing condenser, consisting of a small brass disc about an inch in diameter, the material in which they flow. When the air waves are long, the attenuation is such that the current is at least one third, at the end of every ten miles, of what it was at the beginning of those ten miles, and a little calculation shows that to talk across the continent without any amplifiers inserted along the line would require an immense amount of power. Yet, by the insertion of fifteen amplifiers or relay stations along the line, the attenuation law is prevented by getting under way, and a ridiculously small power is enough for proper transcontinental land line telephony.

There are several methods of controlling feedback, either by a variable tlexer as in A or by a variable resistance shunted across a fixed tlexer coil. Another method is by the use of a variable condenser, as illustrated in B.

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**NATIONAL IMPEDAFORMER "TYPE B"**

A compact unit for simple construction of impedance-coupled audio amplifiers. Contains choke coil, 0.1 Mfd. condenser, and grid leak. Each set of three includes first-stage unit with additional R. F. Choke; second-stage unit with grid leak, condenser and choke, and third stage unit with resistor on plate side and impedance on grid of power tube, to stabilize the amplifier and prevent motor-boating with "B" eliminators.

Price each $5.50

*Write for Bulletin 130*

**NATIONAL SHORT-WAVE EQUIPMENT**

for use with 222 tube

The NATIONAL Velvet Vernier Dial Type E and special Equicycle Short-Wave Condenser are now offered by NATIONAL RADIO PRODUCTS, INC., for experimental work in short-wave reception of broadcast, code and television signals. Also offered are newly designed short-wave R. F. Transformers in a set of 4, covering the bands from 15 to 15 meters, R. F. Choke, H. F. Impedance, special Panel and sub-Panel with all sockets and mounting clips.

*Write for Short Wave Bulletin 128*

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**No. 4**

**RADIO BROADCAST Laboratory Information Sheet**

**The Browning-Drake Circuit**

**Transformers**

**PRIMARY-SECONDARY RATIOS**

The ordinary commercial iron-core transformer consists simply of two coils of wire wound on the same core. So long as the secondary of such a transformer is opened circuit, or connected to something with an impedance so high that not much current flows, we have a very simple relation between the voltage induced by the secondary and that applied to the primary. This relation states that the ratio of the two voltages is the same as is the ratio of the primary and secondary turn numbers. A ten to one step-up transformer would be one with ten times as many turns on the secondary as on the primary.

A transformer corresponds to gears in mechanics. If by an arrangement of gears or levers we increase a mechanical force ten times, we know instinctively that we must expect the part of the arrangement that is exerting the "stepped-up" force to move ten times so slowly as the part where the original force is being applied. If we choose to gain in force, we lose correspondingly in speed, or else we could get "something for nothing." The electrical transformer is not a source of power. It merely changes the power put into it at one voltage into the same power (with a small percentage loss) at a different voltage. Hence, just as the speed went down in the mechanical case, so the current is less in the high tension or high voltage side of the transformer. The primary current is related to the secondary current as the secondary voltage is related to the primary voltage. An auto transformer is no different except that the winding having the fewest turns is merely a part of the other winding. Thus only one coil is required.

There are several simple formulas regarding transformers that are quite useful:

- **Primary Turns**
- **Primary Voltage**
- **Secondary Turns**
- **Secondary Voltage**
- **Secondary Current**
- **Primary Voltage**
- **Secondary Voltage**
- **Primary Current**

Values obtained by the use of the above relationships will serve as fairly close approximations. In general, the smaller the load being supplied by the transformer, the more correct this data will be.

---

**No. 5**

**RADIO BROADCAST Laboratory Information Sheet**

**Dielectric Constant**

The capacity of a condenser depends upon several different factors, the most important of which are: 1. Area of plates, 2. Number of plates, 3. Distance between plates; 4. The dielectric or insulating material between plates.

The effect of the first three quantities on the capacity is easily calculated by means of formulas, the larger condensers, of one or two microfarads capacity, oiled paper is generally used. Its use helps to reduce the con in the break-down voltage of such a condenser will be greater than that of plain paper is used.

Solid dielectrics have the disadvantage that if they are once broken down and punctured, due to excessive voltage, they are ruined forever. However, if a liquid dielectric is used, this disadvantage cannot exist, and for this reason laboratory condensers of fairly large capacity are frequently used. In this way it is not only possible to obtain variable condensers with a fairly large capacity (the capacity of any given condenser by the use of castor oil is made five times as great as it would be if air were used), but also is possible to apply greater voltages without sparking between plates. The capacity of any given condenser is proportional to the constant of the dielectric that is used.

Some of the most common materials used as dielectrics are listed in the table given herewith.
Henderson says, "Play Safe with PARVOLTS!"

"We think as well of ACME PARVOLTS Condensers that we have samples constantly on display for all clients to see. Some of our customers who know radio also know that PARVOLTS are thoroughly reliable. We like our clients to realize that we use the best in radio."

Should a condenser blow out, many dollars would be lost in ruined tubes, transformers, chokes, and other parts. The experience of the nationally known house of Rositer, Tyler & McDonell should be a good guide for other builders and service men to follow. Don't take any chances with condenser breakdown. Play safe with ACME PARVOLTS.

---

**No. 7**

**RADIO BROADCAST Laboratory Information Sheet**

**The New Tubes**

<table>
<thead>
<tr>
<th>Type</th>
<th>A Battery Volts</th>
<th>Filament Terminals</th>
<th>A Battery Current</th>
<th>B Battery Volts</th>
<th>Negative Battery</th>
<th>Plate Capacitance (Milli-ampere)</th>
<th>Output Voltage (Omm)</th>
<th>Voltage Amplitude Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>199</td>
<td>4.5</td>
<td>3.0</td>
<td>.06</td>
<td>45</td>
<td>90</td>
<td>4.5</td>
<td>2.5</td>
<td>15,000</td>
</tr>
<tr>
<td>200</td>
<td>6</td>
<td>5</td>
<td>1.0</td>
<td>15 to 25</td>
<td>90</td>
<td>4.5</td>
<td>9.0</td>
<td>12,000</td>
</tr>
<tr>
<td>201-a</td>
<td>6</td>
<td>5</td>
<td>.25</td>
<td>45</td>
<td>90</td>
<td>4.5</td>
<td>2.6</td>
<td>14,000</td>
</tr>
<tr>
<td>12</td>
<td>1.5</td>
<td>1.1</td>
<td>.25</td>
<td>223 to 45</td>
<td>90</td>
<td>4.5</td>
<td>2.8</td>
<td>6000</td>
</tr>
<tr>
<td>200</td>
<td>8</td>
<td>5</td>
<td>2.0</td>
<td>233 to 45</td>
<td>90</td>
<td>5.6</td>
<td>2.8</td>
<td>7400</td>
</tr>
</tbody>
</table>

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**No. 8**

**RADIO BROADCAST Laboratory Information Sheet**

**Condensers**

_A simple explanation of condenser action_

The accompanying diagram shows the construction of a condenser and also a simple analogy for its action. The crank and piston arrangement, when rotating, produces an alternating current of water which fills the system. A thin rubber diaphragm prevents any direct circulation, but, by bending back and forth, allows alternating motion of the water. The greater the area of the diaphragm, the thinner it is, and the more flexible it is, the easier it will be to turn the crank to operate the piston. (Hence the diagram) the piston connecting rod is hinged to point B of the free wheel instead of point D, all half the force will be required to turn the crank, as the diaphragm will only be stretched half as much. Also, the current will be only half as great. But if then, the crank be turned twice as fast, the speed of the water will be doubled so that the current is the same as before. This establishes a relation that holds good in the electrical case, namely, that if the frequency be doubled, or trebled, etc., the electromotive force required to produce the same current will be only one half, or one third, etc., as great. In the electrical case, corresponding to the diaphragm we have a sheet of some insulating material (dielieic) separating the two plates, or sets of sheets, of the condenser. By increasing the area of the metal plates, thinning the insulating material, this corresponds to increasing the spacing between the plates), or employing dielectric with a high "constant," (see Laboratory Sheet No. 6), the value of the applied voltage to produce a given current is proportionally decreased. Fixed condensers usually consist of metal foil cut up into small pieces which are connected together, and separated with mica or some other dielectric. There are two distinct sets of plates, corresponding to the rotor and stator plates of a variable condenser. The "capacity" of the condensers used in radio circuits is usually expressed in microfarads, and is determined by the insulating substance between the plates, the area of one of the plates (measured in square centimeters) divided by 1,200,000 (times the distance between the plates measured in centimeters). If other insulating material is used, it is necessary to multiply by its dielectric constant. The dielectric constant of mica, for example, is about 6. From this explanation it is evident that current never actually flows through a condenser, but that it merely, we might say, "collects on the condenser plate, and then returns back to the starting point."

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**No. 9**

**RADIO BROADCAST Laboratory Information Sheet**

**Data on the Roberts Four-Tube Receiver**

_COIL DETAILS, ETC._

_ON SHEET NO. 10, lower left corner of the popular four-tube Roberts receiver, it is quite an easy matter to wind coils for this receiver, and there are given below complete data regarding their construction._

_L_ = 60 turns No. 22 d.c.c. wire wound on a 3" cylindrical form. The coil is to be tapped every 10 turns.

_La_ = 15 turns No. 22 d.c.c. wire wound on a 3" cylindrical form. The coil is to be tapped every 5 turns.

_Lb_ = 10 turn bunch-wound coil of No. 26 d.c.c. wire wound at the center and wound over the filament of the secondary winding, Lc.

_Lc_ = 25 turns No. 22 d.c.c. wire wound over a 3" form.

_Ld_ = 20 turns No. 26 d.c.c. wire wound on a cylindrical form and wound at the grid end of the secondary winding. Lb.

_Based upon data, the following additional apparatus in order to construct the receiver._

_G_ = Grid variable condenser. 4.5 volt B battery. 9 volt C battery. Double-circuit jack. Single-circuit jack 10-ohm rheostat 10-ohm rheostat 0.00025-mfd. grid leak and condenser 0.0005-mfd. condenser and 4-megohm grid leak.

_After the receiver has been completely built, it should be neutralized. The following method of doing this will, in general, be successful. First, tune-in some local station that is broadcasting with a frequency of sou 100 k.c. (1000 meters). Advance the tickler until the detector begins to oscillate. Now, by varying the setting of the first condenser, it will be found that the pitch of the whistle will change. The variation of the pitch of the whistle is due to the fact that the radio frequency stage is oscillating, and this produces the oscillations in the detector stage. When the receiver is properly neutralized, oscillations will not take place in the radio frequency amplifier, and the pitch of the whistle will not change. The problem is, therefore, to so adjust the neutralizing condenser as to bring about this condition. When the receiver is properly neutralized, the tuning of the first condenser will have no effect on the tuning of the second condenser._

---

**ACME PARVOLT FILTER CONDENSERS—**

The ACME PARVOLT FILTER CONDENSERS, as described in the latest catalog, are supplied in standard sizes.科有'realistic' values and in the form best suited for the particular purpose. We supply PARVOLTS in all diameters and widths for the purpose. We supply PARVOLTS in all diameters and widths for the purpose. We supply PARVOLTS in all diameters and widths for the purpose. We supply PARVOLTS in all diameters and widths for the purpose.
Write for this Book

HAMIARLUND ROBERTS CUSTOM BUILT RADIO

Hi-O 20 Construction Manual

"The Best in Radio"

Send 25 cents for your copy before first edition is exhausted.

HAMIARLUND-ROBERTS, Inc.
1892 Broadway, New York City

80-Page Manual Tells How to Build

4 NEW Hi-Q RECEIVERS and Save Money

THIS is the biggest and most complete Construction Manual ever published by Hammarlund-Roberts. 80 pages of text, photos and diagrams on how to build the New Hi-Q Receivers and save money! Each of these new Hi-Q Receivers is a distinct advance over any Hi-Q Receiver of the past 4 years—each is a completely shielded "coast-to-coast" instrument—each is a marvel in selectivity and sensitivity—each has even finer tone than any of the famous Hi-Q instruments of the past. And each can be built, by following the simple directions in the Hi-Q Manual, at SAVINGS of $50 to $100 over any ready-made receiver of anything like similar efficiency.

This New Manual also covers power amplification construction, short wave adapters, installation, high efficiency battery and tube combinations, antenna, house wiring and a wealth of other practical information.

Shows you how to build a fine radio for yourself AT A SAVING and how to build for others AT A PROFIT.

Send 25 cents for your copy before first edition is exhausted.
No. 13

Radio Broadcast Laboratory Information Sheet

Charging Storage Batteries on Direct Current

Necessary Resistances, etc.

If one has a convenient source of direct current, it is comparatively simple matter to charge storage batteries. Although such charging will no doubt be cheaper, and much more convenient than having one's wires, there is at least the chance that it will be equally as safe. The charging may be accomplished by either of the two methods illustrated in the diagram. In the former, the charging rate is determined by the value of the resistance r. Most of the power companies supply 110 to 120 volts, and for this line voltage the following values of resistance should be used:

<table>
<thead>
<tr>
<th>Voltage of the charge</th>
<th>Resistance (ohms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-10 volts, 100 watts</td>
<td>55, 33, 50</td>
</tr>
<tr>
<td>5-10 volts, 50 watts</td>
<td>22, 33, 50</td>
</tr>
<tr>
<td>5-10 volts, 15 watts</td>
<td>11, 33, 100</td>
</tr>
</tbody>
</table>

The last column is given so that if a resistance unit is purchased care can be taken in choosing one that is capable of dissipating the power given in the table.

In place of the resistance units we can substitute a bank of electric lights as is illustrated in Figure 1, B. The charging rate will be determined by the total wattage of the entire bank of lamps, and this total will equal the sum of the individual wattages of all the lamps. If five 40-watt lamps are used, the total will be 200 watts. If the bank consisted of one 40-watt lamp, one 150-watt lamp, and one 50-watt lamp, the total would be 200 watts. By reference to the table, the total power (wattage) required, for any value of charging rate, can be found in the last column.

There are some precautions to be taken. In the first place, be sure to connect the positive side of the loop to the positive side of the battery. If the battery is wrongly connected, it is likely that the leads will become damaged. Secondly, be sure that none of the leads touch any metal surfaces, such as water pipes, for if this occurred a short-circuit might result. Thirdly, be certain that the charging rate is not too high. Information regarding this is given on the name plate of the battery. However, if this information is lacking, the charging rate should be determined by the heating of the electrolyte. As the charging rate increases, the temperature of the solution gradually increases, and no damage will result if the temperature is not allowed to exceed 110 degrees Fahrenheit.

No. 14

Radio Broadcast Laboratory Information Sheet

A Batteries

The Dry Type

For the majority of receivers using type 199 tubes, a bank of dry cells can be used to advantage. For portable sets such an arrangement is very convenient, and although, in general, the operation of these tubes will be found somewhat more expensive than storage battery sets, their greater convenience usually more than compensates for the greater cost of upkeep.

The common type of dry cell usually consists of a zinc container (which also acts as one element of the battery) in which is placed a paste consisting of powdered charcoal and manganese dioxide moistened with a solution of sal ammoniac. Between the zinc container and the active material, there is usually placed a layer of blotting paper. The paper absorbs the acid, which holds the electrolyte, but does not prevent the zinc from coming into contact with the carbon. In such contact does occur, an internal short-circuit takes place and the cell becomes useless.

The zinc case of the cell forms the negative pole, and the positive terminal is a carbon rod that is placed in the center. This carbon rod is insulated from the zinc shell and does not react chemically with any of the other substances used.

The current from any one cell should not exceed one-quarter ampere. In case of portable sets, it is not always possible to use that number of cells which would give greatest efficiency. In any case the current in the home, arrangements should be made to use sufficient cells for other operating.

For any receiver using up to four 199 tubes, only three dry cells are required, connected as is shown in Figure 1 on the accompanying diagram. If the receiver uses more than four 199 tubes, two banks of dry cells should be used connected as shown in B.

Dry cells can be treated most readily by means of an ammeter. The instrument should be capable of reading up to about 50 amperes, and in testing the cell, it should be connected as in C. The cell should be thrown away if it reads less than five amperes.

No. 15

Radio Broadcast Laboratory Information Sheet

Loop Antennas

Theory of Operation

A Loop Antenna is quite commonly used in combination with multi-tube receivers, especially super-heterodynes. The action of a loop is not quite so simple as is sometimes taken for granted in the case of a simple antenna.

The theory of the operation of a loop is commonly explained in the following manner. Suppose we have two vertical wires separated by a distance of 200 meters, both of them insulated from each other and from the earth. A wire is passed from a direction perpendicular to the plane of the two wires, and the voltages induced will be exactly in phase. If the wave approaches from the other direction, it will reach the two wires at different times and, therefore, the induced voltages will be in phase. Thus in these approaches in the direction of the plane of the two wires, the induced voltages will be 180 degrees out of phase. However, the voltage at the upper end of one wire will be a positive maximum when the voltage at the upper end of the other wire is at a negative maximum. Now, if the upper ends are connected together and the input to a receiver is connected across the lower ends, current will flow around the circuit, and if the circuit is tuned by a condenser, the currents will become comparatively large. The induced voltages will be greatest when the wave and the loop are both in the same plane, since this will result in maximum phase displacement between the voltages induced in the front and rear wires of the loop.

With regard to the design of loops, it will generally be found that the current induced in the loop varies directly as the area, directly as the number of turns, inversely as the resistance, and inversely as the length of the wave being received.

The common type of loop antenna consists of several turns of wire wound on a rectangular form. The turns should be spaced about one half an inch from one another, so as to keep the capacity low. The efficiency of the loop also increases with the number of turns. This capacity increases rapidly with the first few turns, and then the rate of increase becomes slower. A very satisfactory magneto loop for use with a 0.0006 mil condenser may be made by constructing a iron square form and winding it on six turns of No. 22 wire. Such a loop would have a capacity of about 1000 kcs. (250 meters) to 600 kc (1000 meters).

Generally, for satisfactory operation, no connection to ground is necessary. However, somewhat lower signal magnitudes may be obtained if the potential end of the loop is connected to ground. When such a connection is made, it is likely that the loop also acts as a small antenna by reason of its capacity to ground. In this connection, it should also be pointed out that the inner end of the loop should always be at the lowest potential.

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Fig. 1—Tonatrol Type P Circuit

Recommended for the following receivers and closely similar types: Gnome (M11); Kohler 6-D; Breuer-Tullay Counterphase 5-377, Fada 8-480 B.S.F. 90/80.

Fig. 2—Tonatrol Type R Circuit

Recommended for Awwater-Kent; Freshman Masterpiece, home-built tuned f. a. sets; the Pargan models; Beach models 66 and 76, and Breuer-Tullay Counterphase.

Fig. 3

Tonatrol Type A Circuit

Antenna Type for Non-oscillating Receivers

Adapted to such stodgy circuits as Fada 7-377 A.S.F. 41-757; Gnome 7; The Beach (Crown); Crosby Anti-Strum; Siemens Carl Sue 19-1; Thermodyne T.P. 7; Zenith 11 or 14.

Fig. 4

Tonatrol Type S Circuit

Audio Control for Non-oscillating Receivers

 Usually used as an auxiliary volume control in addition to an oscillator or regeneration control. Generally improves tone quality.

ELECTRAD

175 Varick Street New York


No. 16 RADIO BROADCAST LABORATORY Information Sheet

Carrier Wave Analysis

HETERODYNE INTERFERENCE

Radio waves travel with the speed of light—300,000,000 meters per second. Now, in any wave motion, the frequency, or number of waves passing a given point in a given time, multiplied by the wavelength, gives the speed with which the waves are traveling. A train of railroad cars passes a given point at the rate of two cars per second and each car is fifty feet long; the speed of the train is obviously one hundred feet per second.

Quite similarly, if the frequency of passing radio waves is one million per second, then the length of each wave must be 300 meters to make the speed come out the value stated above. Broadcasting stations have a frequency separation of 10 kilocycles to prevent heterodyning, and no uniform wavelength separation can be given that will be applicable throughout the broadcasting band. If we work with wave lengths, we can calculate anew the width of channel expressed in meters for every different wavelength. Thus a 10-kilocycle channel at three hundred meters wavelength is only a three-meter channel, while at three thousand meters wavelength, it is a three-hundred-meter channel. There are about nine times as many 10-kilocycle stations available at shorter wavelengths as at 300 and 3000 meters as there are between 300 and 30,000 meters.

For very high quality music, all tones between about 30 and 5000 vibrations per second should be transmitted with equal efficiency. To transmit the former, we must transmit a frequency 30 cycles greater than the carrier and another 30 cycles less than the carrier, in addition to the carrier itself. To transmit the 6000-cycle note we must use the frequencies 5000 greater than 6000 less than the carrier, and to transmit all intermediate tones, we must use the two bands of frequencies (called the upper and lower side bands) shown in the accompanying diagram.

The whole range of frequencies used is called a “channel.” In the case just described, the width of the channel is 10,000 cycles. The important thing about all this is that broadcasting stations do not use only a single frequency or wavelength as might be supposed from the figure given at the top of the newspaper radio programs (that figure is the frequency of their carrier wave in kilocycles per second), but they each require a channel of definite width, and hence only a rather small number can be used at once without the stations overlapping. Overlapping results in a continuous whistling sound (of which pitch diminishes somewhat with overlap on frequency, and of lower pitch if the overlapping is greater).

No. 17

RADIO BROADCAST LABORATORY Information Sheet

Inductance of Single-Layer Solenoids

CALCULATION FORMULA

It is possible to obtain quite a close approximation of the inductance of a single-layer coil by the use of the Bureau of Standards formula, which is as follows:

$$L = \frac{n^2 \mu_0}{K}$$

in which

- $L$ = Inductance of coil in microhenries.
- $n$ = Radius of coil in inches, measured from the center of the coil to the center of any wire.
- $K$ = A constant, depending upon the ratio of $b/a$.
- $b$ = Length of coil, in inches.
- $a$ = Number of turns.

The constant $K$ in the formula can be obtained from the accompanying curve.

This formula is not too well in determining the approximate inductance of any particular coil, or can be used to determine the number of turns necessary in order to get inductance.

It does not take into account the shape or size of the wire, nor does it consider the effect of the capacity of the coil. However, since the coil capacity is usually negligible in comparison with the capacity of the tuning condenser, it is not especially important in so far as the tuning range of the coil is concerned.

No. 18

RADIO BROADCAST LABORATORY Information Sheet

Volume Control

CORRECT METHOD TO USE

A GREAT many of the present receivers now in use are not equipped with any really satisfactory means of volume control. The most common method used on these receivers is to control volume by means of one or more filament rheostats. Usually these rheostats control the audio frequency tubes and, with it the case, the quality is sure to suffer when the volume is reduced by lowering the filament current. Under such conditions, the quality will be impaired due to the following causes.

In the first place, lowering the filament temperature will increase the grid leak, and, as the filament temperature decreases, the frequency characteristic curve of any audio transformer will shift to a grid bias, increasing the impedance of the secondary circuit. If this impedance is high, the quality will be poorer than if the impedance was low, and for best results in impedance of the transformer, primary should be at least three times the minimum impedance of the load. Lowering the filament temperature will destroy this ratio, and the quality thereby becomes poorer.

In the second place, lowering the filament temperature has the same effect as increasing the negative grid bias. If the temperature is lowered to any great extent, the tube will operate on the lower bend of its characteristic curve and distortion of the signals will then take place because a certain amount of detection will occur. Detection should only take place in the detector circuit, and if it occurs at any other point, it will invariably cause distortion.

If volume control is at present being accomplished by filament rheostats in the audio amplifier, it will be wise to rewrite the set so as to permit the use of some other system.

Volume can be controlled quite satisfactorily by means of a potential-meter across the secondary of the first audio transformer. This resistance will, actually somewhat better the quality, since, if a second transformer is being used, it will smooth out the amplification curve and make it quite flat. This unit should have a capacity of about 500,000 ohms, and should always be placed across the line audio amplifier, if it is then possible, on strong signals, to cut down the volume and incidently prevent overloading of the audio tubes. However, if the resistance is connected across the secondary transformer, it would not be possible to prevent overload- ing of the first tube. Connection across the first transformer is, therefore, advisable.

It is also possible to control volume very nicely by means of the filament rheostat controlling the audio frequency transformer, without getting into any of the difficulties that occur if filament variation of the audio frequency transformer. It is used control voltage of the coil due to the fact that variations in the plate impedance of the radio frequency tube merely tend to cut down the overall amplification, and there is no possibility of frequency distortion since we are working with what is practically a single frequency.
Learning to Read Code

To learn the Morse code by heart requires a lot of practice. It is essential to practice every day, even if it is only for a few minutes. Initially, it is best to memorize the letters and numbers, starting from the beginning of the alphabet. Then, practice combining them into words and sentences.

For example, to write the word "HELLO" in Morse code, you would use the following sequence:

H: .----
E: ....
L: --...
L: --...
O: ---

After a while, you will be able to read and write Morse code without having to look at the alphabet. This will make it easier to communicate with other radio operators around the world.
THE unqualified endorsement of Ceco Radio Tubes by the leading radio engineers, including Cockaday, Lynch, Hurd, Bernard and many others, is conclusive evidence of their proven performance.

Their uniformly high-quality materials make it possible to make up a very simple yet quite efficient loop receiver using condenser feedback for the control of regeneration. Such a receiver will be useful for local reception when sufficient audio frequency amplification is added. If the receiver is made up in the form of a portable set, it will also be found extremely valuable in locating sources of interference.

The circuit diagram of such a receiver, using two stages of audio amplification, is given herewith.

For the simplest form of regeneration, a single 0.0005-mfd. variable condenser may be used to control regeneration. This condenser may consist of about 300 turns of No. 0 d.s.c. or other fine wire, bank wounded on a 1-by-1-inch tube.

Audio frequency transformers.

A single-circuit filament control jack is provided. If the set is to be designed for portable use, tubes are recommended and, in this case, it is best to supply the filaments with batteries in series. The tuning of the receiver is quite simple and the amount of resistance in the rheostat in order to control the tubes. The values of resistance must just be sufficient to reduce the necessary amount, and if it is found that a filament has been supplied with too much voltage, the tubes may be damaged.

No. 22

A Simple Loop Receiver

No. 23

DETERMINING CORRECT NUMBER OF TUBES IN PARS

<table>
<thead>
<tr>
<th>TYPE OF TUBE</th>
<th>NUMBER OF TUBES</th>
</tr>
</thead>
<tbody>
<tr>
<td>201-1 - 6-Volt</td>
<td>1</td>
</tr>
<tr>
<td>199-1 - 6-Volt</td>
<td>2</td>
</tr>
<tr>
<td>102-1 - 11-Volt</td>
<td>2</td>
</tr>
<tr>
<td>103-1 - 11-Volt</td>
<td>2</td>
</tr>
<tr>
<td>120-1 - 6-Volt</td>
<td>2</td>
</tr>
<tr>
<td>121-1 - 6-Volt</td>
<td>2</td>
</tr>
</tbody>
</table>

No. 22

RADIO TUBE
for A.C. sets

CECO

RADIO TUBE
for A.C. sets

CECO
RADIO BROADCAST'S DATA SHEETS

No. 19

RADIO Broadcast Laboratory Information Sheet

Learning to Read Code

A GOOD CIRCUIT TO USE

ONE of the best methods for use by a novice....

Practically all of the transatlantic stations operate on these frequencies, and usually the transmitting is done on a fairly low speed, so that if it is possible for anyone with a rudimentary knowledge of the code to decipher quite a few letters in a comparatively short time it will be found possible to receive whole words—and then sentences.

The circuit diagram of a long-wave receiver that can be used to receive code signals is shown in the accompanying diagram. L is a honeycomb coil, the size of which depends upon the wavelength it is desired to receive. Condenser C is a ordinary 0.00004 microfarad variable, and forty-five volts of B battery is sufficient. This receiver is regenerative, and is feedback controlled by variation of the 20-ohm filament rheostat.

The receiver should be connected to an antenna about 100 feet in length, and a good ground should be used. Most of the long-wave stations operate on pure c.w., which means that the antenna at the transmitter is fed from a high frequency oscillator, the output of which is controlled by the key. When the key is depressed the set breaks into oscillation and when the key is raised the set stops oscillating. Therefore, the energy radiated into the air consists of a series of high frequency impulses. These signals are not audible until they are heterodyned by the oscillations that take place in the receiver. Therefore, in using this receiver, the filament rheostat should be advanced until it oscillates. A copy of the International Morse Code is shown on Sheet No. 20.

The following table gives the coil sizes for L to cover the various wavelength bands commonly used—

<table>
<thead>
<tr>
<th>Coils (mils)</th>
<th>Frequency Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 mils</td>
<td>750 to 1000 kHz</td>
</tr>
<tr>
<td>2000 mils</td>
<td>1500 to 2000 kHz</td>
</tr>
<tr>
<td>3000 mils</td>
<td>2500 to 3000 kHz</td>
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<tr>
<td>4000 mils</td>
<td>3500 to 4000 kHz</td>
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<tr>
<td>5000 mils</td>
<td>4500 to 5000 kHz</td>
</tr>
<tr>
<td>6000 mils</td>
<td>5500 to 6000 kHz</td>
</tr>
<tr>
<td>7000 mils</td>
<td>6500 to 7000 kHz</td>
</tr>
<tr>
<td>8000 mils</td>
<td>7500 to 8000 kHz</td>
</tr>
<tr>
<td>9000 mils</td>
<td>8500 to 9000 kHz</td>
</tr>
<tr>
<td>10000 mils</td>
<td>9500 to 10000 kHz</td>
</tr>
</tbody>
</table>

No. 20

RADIO Broadcast Laboratory Information Sheet

The Morse Code

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>.</td>
<td>0.005</td>
<td>D, G, N</td>
<td>E, H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>.-</td>
<td>0.015</td>
<td>B, C</td>
<td>F, M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>0.04</td>
<td>A, L, R</td>
<td>I, O</td>
<td></td>
<td></td>
</tr>
<tr>
<td>.-</td>
<td>0.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.-</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.-</td>
<td>0.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No. 21

RADIO Broadcast Laboratory Information Sheet

Rejuvenating Tubes

CONSTRUCTION OF A SUITABLE UNIT

IT is not infrequently happens, that, with tubes having been stored and filled, the emission gradually decreases. After considerable use so that the tube is rendered useless, even though the filament still light. One of the conditions that may subject the tubes to a treatment that will put them once more in service. The treatment is called rejuvenation, or rejuvenation. and is quite easily accomplished by the home experimenter with a few fairly cheap parts that can be obtained in to a suitable instrument for reconditioning the tubes. Many tubes will, after rejuvenating, give the same amount of emission as they did when new. The part of the tube to rejuvenate is a toy transformer, and is employed to operate small electric transformers. Many tubes can be rejuvenated and some ballasts, etc. The connections are clearly shown in the accompanying diagram. Practically all toy transformers have a small switch by means of which the secondary voltage can be raised or lowered. Voltages from six to twelve can usually be obtained. Suppose we desire to recondition a 201-A. The tube is placed in the 201-A socket (which is the left hand socket in the diagram) and the plug connected to the 110-volt alternating current supply. The tap switch is set for twelve volts and the tube is allowed to burn at high voltage for about one minute. The voltage is then reduced to six volts, and the tube is permitted to "cook" for about one-half hour. It can then be removed and, generally, when placed in a receiver, it will be found to give entirely satisfactory operation.

A copy of the International Morse Code is shown on Sheet No. 20.

No. 21

RADIO Broadcast Laboratory Information Sheet

Rejuvenating Tubes

CONSTRUCTION OF A SUITABLE UNIT

IT is not infrequently happens, that, with tubes hav-

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No. 22

RADIO BROADCAST Laboratory Information Sheet

A Simple Loop Receiver

GENERAL DATA

It is possible to make up a very simple yet quite efficient loop receiver using condenser feedback for the control of regeneration. Such a receiver will be useful for local reception when efficient audio frequency amplification is added. If the receiver is made up in the form of a portable set, it will also be found extremely valuable in locating sources of interference.

The circuit diagram of such a receiver, using two stages of audio amplification, is given below.

\[ L_1 = \text{Any standard loop designed for operation with a 0.0005-mfd. variable condenser.} \]
\[ C_1 = 0.0005-	ext{mfd. variable condenser.} \]
\[ R = \text{5-ohm grid leak.} \]
\[ C_2 = 0.0005-	ext{mfd. grid condenser.} \]
\[ K = \text{Radio frequency choke coil. This coil may consist of about 300 turns of No. 16 d.c. o.} \]
\[ \text{other fine wire, hawk wound on a 3-inch tube.} \]
\[ T_1 = \text{Audio frequency transformer.} \]
\[ R_h = \text{A single-circuit filament control jack.} \]
\[ R_a, R_b, \text{and } R_s = \text{filament ballast resistances of type satisfactory for the kind of tubes employed.} \]

If the set is to be designed for portable use, un-199 tubes are recommended and, in this case, it will be best to supply the filaments with 1.5-volt dry batteries in series. The tuning of such a receiver

is quite simple and depends entirely upon the setting of the condenser \( C_1 \). As in any regeneration receiver, maximum volume will be obtained when the detector tube is adjusted so as to receive slightly below the oscillating point, this adjustment being controlled by variation of the condenser. Particularly in interference investigations the directional effects of the loop will be found very valuable, the loudest interference being received when the plane of the loop is pointed toward its source.

![Diagram of A Simple Loop Receiver](image)

At all times during the operation of the receiver, care should be taken to see to keep the detector tube below the oscillating point since, if this tube does oscillate, a certain amount of radiation will take place which will produce interference with other receivers. Since a loop is being used, this radiation will not be very great, however.

No. 23

RADIO BROADCAST Laboratory Information Sheet

Rheostats

DETERMINING CORRECT VALUES

ON THIS SHEET are given data regarding the amount of resistance necessary in a single rheostat to control various numbers of tubes. The values of resistance that are given are just sufficient to reduce the battery voltage by the necessary amount, and it is desired to operate the tubes at somewhat below their rated voltage (not al-

Number of Tubes in Parallel | Type of Tubes
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>201-A—With 6-Volt Supply</td>
<td>4</td>
<td>2</td>
<td>1.5</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td>199—With 6-Volt Supply</td>
<td>25</td>
<td>13</td>
<td>9</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>199—With 6-Volt Supply</td>
<td>50</td>
<td>25</td>
<td>17</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>12—With 11-Volt Supply</td>
<td>1.6</td>
<td>.8</td>
<td>12</td>
<td>.8</td>
<td>4</td>
</tr>
<tr>
<td>12—With 12-Volt Supply</td>
<td>1.6</td>
<td>.8</td>
<td>12</td>
<td>.8</td>
<td>4</td>
</tr>
<tr>
<td>112—With 6-Volt Supply</td>
<td>2</td>
<td>1</td>
<td>.7</td>
<td>.5</td>
<td>.4</td>
</tr>
<tr>
<td>120—With 6-Volt Supply</td>
<td>12</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>120—With 6-Volt Supply</td>
<td>24</td>
<td>12</td>
<td>8</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

No. 24

RADIO BROADCAST Laboratory Information Sheet

Bypass Condensers

RULES FOR LOCATION

AT SEVERAL locations in a receiver it is essential that bypass condensers be used and, at several other points, their use is advisable. In practically all receivers, a bypass condenser is necessary across the primary of the first audio transformer, which is, of course, connected in the plate circuit of the detector tube. In those cases where transformer coupled amplification is not used, the condenser should be placed across the impedance or resistance in the detector plate cir-

![Diagram of Bypass Condensers](image)

2.. With the former method of connection, the radio frequency currents are returned, by the condenser, directly to the filament and do not need to pass through the B battery. The condenser used at this point should not be so large as to be necessary to give good results. Usually a 0.001-ES-mfd. condenser is large enough, and a 0.001 mfd. should not be used unless it is found necessary. It is frequently wise to place a large bypass condenser across the B battery. This condenser, which should have a capacity of about 1 mfd., bypasses the audio currents around the B battery.

A condenser connected as shown in C, will usually be found of value in obtaining more stable operation from a radio-frequency amplifier. In this circuit, the condenser is not used, the r.f. currents, in returning to the filament, must pass through various leads and then through the B battery, and, quite possibly, there will be sufficient coupling to other parts of the circuits to prevent accurate neutralization. This condenser should have a value of not less than 0.1 mfd.

The function of any bypass condenser is to return certain currents, by as short a path as possible, to the tube where they originated. A bypass condenser is practically worthless if connected to any part of the circuit without giving regard to this rule. Therefore, whenever possible the use of the bypass condenser should connect to the filament terminal of the socket containing the tube to which the currents are to be returned.
Modulation

THE process of impressing audio frequency currents on the radio frequency output of a transmitter is called "modulation.

The simplest case of modulation occurs when a musical note of audio frequency, such as in production by a tuning fork, is transmitted. If the tuning fork is moved in such a way that the sound produced by the fork will be transmitted by the microphone, these audio frequency currents will cause the radio-frequency waves to vary in intensity in sympathy with them. If the radio wave without any modulation had a frequency of 500,000 cycles, and the audio-frequency current was transmitted by the tuning fork, the radio-frequency wave would change its frequency and would be composed of three frequencies, one equal to the original frequency of 500,000 cycles, another equal to 499,000 cycles, and another equal to 501,000 cycles.

These last two frequencies are equal, respectively, (1) to the difference between the original, or carrier frequency, and the audio frequency, and (2) to the sum of the carrier and audio frequency. In actual transmission, we are not dealing with a single 500,000-cycle but with a large band of frequencies between approximately 50 and 5000 cycles, so that all of these various frequencies are impressed on the carrier wave during modulation.

The most common method of modulation used by broadcasting stations is the Heting method, and it is shown in its elementary form in the diagram on laboratory sheet No. 26. Here tubes No. 1 is the oscillator, and No. 2 the modulator. The choke coil L is sometimes called the Heting choke. The oscillatory circuit is the familiar Hartley type used with an inductively coupled antenna coil. This voice signals are impressed on the grid of the modulator tube as is shown in the diagram. Actually, between the microphone and the modulator tube, it would be necessary to use several stages of additional amplification. The audio signals impressed on the modulator cause its plate current to vary and produce a corresponding plate-current variation in the oscillator tube.

The total current supplied to the circuit by the battery supply, marked B on the diagram, does not vary appreciably as the modulation increases on the grid of the modulator tube No. 2, due to the fact that the choke coil has a very high inductance and, therefore, offers considerable impedance to any variation in the current flowing through it. This Heting choke coil is an essential part of a radio transmitter using this type of modulation.

If a radio wave is completely modulated, the power transmitted will be about one and a half times as much as an unmodulated wave having the same average current. However, in ordinary broadcasting, it is not advisable to completely modulate the carrier and, therefore, it can be said that the power transmitted when the wave is being modulated is about the same as the power transmitted when the wave is not being modulated.

The Three-Electrode Tube

THE three-electrode tube can be used in a great many ways, but its use in connection with radio transmission and reception is confined almost exclusively to the following:

1. MODULATION: Vacuum tubes are used in this connection in all the large radio broadcasting stations throughout the world. Modulation can be done by the process of varying the amplitude of the transmitted radio waves in accordance with the variations of pressure in the gas that constitute the voice or music. The actual process of modulating the power of a high-power station, in general, requires considerable essential auxiliary apparatus. However, modulation can be accomplished using a single circuit such as that shown in the accompanying diagram, where tube No. 2 is the modulator. A careful analysis of modulation appears on sheet No. 25.

2. RECTIFICATION AND DEMODULATION: This is the process of converting modulated radio-frequency alternating currents into direct currents varying in strength in accordance with the original voice or music.

3. REGENERATION: The process of neutralizing the unavoidable resistance in the receiving circuits, resulting in greater currents being produced by the incoming waves.

4. AMPLIFICATION: Increasing the energy of either radio or audio (voice and music) frequency currents, without changing their form. The tube itself is an amplifier, the ordinary type giving an output voltage about five times greater than the input voltage. The tube may function as an amplifier with the modulator turned off, in which case an even greater overall amplification is obtained.

5. OSCILLATION: The production of high-frequency alternating currents. At the transmitting stations it is high frequency current flowing in the antenna that radiates energy in the form of electromagnetic waves (in this case, radio waves). Tube No. 1 is an oscillator in the diagram shown.

A Voltmeter Made From a Milliammeter

IN THE course of their experiments, most home constructors acquire one or more d. c. milliammeters for use in measuring the plate current of tubes. These instruments are comparatively cheap and are essential in making general tests on radio parts.

Another very useful instrument is the d. c. voltmeter for use in measuring the voltage of all kinds of batteries and similar devices. It is possible to make up a very useful and fairly accurate volt- meter using a d. c. milliammeter and a good fixed resistance, and thereby make unnecessary the purchase of a voltmeter. Actually, a voltmeter consists of a sensitive milliammeter in series with a high resistance. In a resistor, in series with the resistance, is placed across known voltages, and its current is measured instead of milliamperes. Suppose we have a meter with a full-scale reading of 2 milliamperes, 1000 microamperes, and we want to use it as a voltmeter for use on line supply devices which supply voltages up to 300. To determine the required resistance in series with the meter, we divide 200 by 2,000, and the quotient, 100,000 ohms, is the resistance in ohms. If we place the milliammeter in series with the 100,000-ohm resistor, we have a voltmeter as shown in the diagram. The needle will deflect an amount proportional to the voltage. We have made our voltmeter so that if the meter reads 2 milliamperes, the voltage is 100; if it reads 1 milliamper, the voltage is 50.

It is not always possible to obtain accurate resistance units to fit in with the scale of voltmeters, and, in general, it is better to calibrate the voltmeter so as to allow for errors in the fixed resistance. On Sheet No. 28 is given information regarding the calibration of a home-made voltmeter, and if the calibration is done carefully, it should be possible to obtain readings which will be accurate within a few per cent. For rough measurements, no calibration is necessary, if good fixed resistances are purchased, their marked resistance value can be depended upon within about ten per cent, usually the per cent error will be even less than this.

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No. 28

Calibrating a Home-Made Voltmeter

PLOTTING THE CURVE

ON LABORATORY Sheet No. 27 were given data regarding the construction of a simple voltmeter from a milliammeter. Information is given here for the calibration of such a meter.

First determine the required resistance in series with the milliammeter by the following formula:

\[ R = \frac{5 \times 1000}{i} \]

where \( R \) is the maximum voltage it is desired to read, \( i \) is the full scale reading of the meter in milliamperes, and \( k \) the unknown resistance.

Example:

1. It is desired to read 500 volts using a 10-milliammeter.

Then \( R = \frac{5 \times 1000}{500} = 1000 \) ohms.

The calibration is performed by placing the fixed resistance and meter across different known volatages and plotting a curve showing the deflection of the meter for different values of voltage.

By making such a calibration, it will be possible to compensate for any inaccuracy in the fixed resistance. If no voltmeter is available whereby the applied voltages for calibrating purposes can be measured, it will be possible to use new B batteries, since the marked voltages will then be quite dependable. First 220 volts could be placed across the combination and the meter reading taken, then 45 volts, etc., until several points are obtained.

No. 29

Tubes: Miscellaneous

213

This is a full-wave rectifier for use with line supply devices. Its filament voltage is 5, and its maximum value of the a.c. input voltage is 220 volts (effective value), and the maximum rectified current the tube can deliver is 65 milliamperes.

216-b

This is a half-wave rectifier for use in line supply circuits. Its filament voltage is 7.5, and its current is 1.25 amperes. The maximum value of the a.c. input voltage is 110 volts (effective value). The maximum rectified current is 65 milliamperes.

874

This tube is used as a voltage regulator and, when correctly connected in a circuit, it functions to maintain a constant voltage. The voltage drop is 90 volts d.c., and the starting voltage is 125 volts d.c. The maximum current is 60 milliamperes. The positive lead is connected to the rod and the negative lead connects to the cylinder. This tube is used in the line supply device manufactured by the Radio Corporation of America and also in their Model 104 loud speaker.

No. 30

Measuring the Output Voltage of a Line Supply Device

REQUIREMENTS OF A SUITABLE METER

CONSIDERABLE care must be taken in measuring the output voltage of a line supply device if an accurate reading is to be obtained. The output voltage of such devices is of critical importance. The critical point is the great extent upon which the current being drawn from them, and if any considerable amount of current is also drawn by the voltmeter which is used in determining the output voltage, the reading will not be accurate and cannot be used.

Also, if results are to be obtained, the output voltages must be measured when the instrument is connected between the current to be measured and a normal load is being drawn from it, since, if these conditions do not exist at the time of the test, the voltage read with the voltmeter will be considerably higher than would actually be applied to a receiving set in operation. A reading taken without any load on the line supply device will sometimes be 100 volts higher than the reading taken with load.

The voltmeter which is used to measure the output voltage must have a very high resistance in order to prevent large currents from flowing through it. On Sheet No. 27 is given information regarding the construction of a home-made voltmeter which can be used.

It is also possible to purchase suitable units for use in measuring the output of B eliminators. In any event, the voltage cannot be at all accurately read if one of the cheaper low-resistance type of meter is used.

An experimental example might make even more evident the errors which will be introduced in the reading, if the cheaper type of voltmeter is used. As an example suppose that we desire to measure the output voltage of a 500-volt A supply device such as was described in the December, 1933, RADIO BROADCAST, if the receiver was drawing from the eliminator 20 milliamperes, the output voltage would be about 120 volts. However, if the test was made with a low resistance meter, the meter reading would be considerably in error. This, of course, is only a typical example if 36 per cent. However, if a high-resistance voltmeter is used, such as is described on Laboratory Sheet No. 27, only about 2 milliamperes will be required by the voltmeter, and the voltage reading would be practically the same as the actual voltage, and a truer indication of the voltage being supplied to the set would be obtained. The care which is necessary in measuring the output voltages of B line supply devices is not necessary in measuring B batteries, since a drain of 20 or 30 milliamperes will make very little change in the output of a B battery. Therefore, it becomes possible to read the voltages of their units with an ordinary voltmeter whether they have a low resistance or not.
No. 31  RADIO BROADCAST Laboratory Information Sheet

Distortion in Receivers

SOURCES AND REMEDIES

There are several points in a receiver where distortion can occur. In the first place, if the radio-frequency amplifier or detector circuits are tuned too sharply, distortion will occur due to the fact that the side bands of the radio frequency wave, which are not equally transmitted by the tuned circuit, and in this way, double frequency distortion is produced. If a grid leak and condenser system of detection is used, there will also be a tendency to overload the detector tube on strong local stations. If this occurs, the various frequencies will not be properly amplified, the detector tube and condenser will produce distortion. For real quality on local stations, a C-Battery detector is advisable since it can handle comparatively larger amounts of signal strength without overload.

Distortion can occur in the audio frequency amplifier. To prevent this, good transformers should be employed, if this form of coupling is used. A C-Battery should always be placed on the grids of all audio amplifiers in order to prevent the tubes from overloading. If overloading does occur, the peaks of the voice waves will be cut off, and serious distortion results. Also, if the wiring of the audio amplifier is rather poorly done, it is not at all impossible that the audio amplifier will begin to oscillate, sometimes as audible frequencies and sometimes at audible frequencies. If the oscillation is audible it can be fairly easily checked up and corrected, but if it is inaudible, it is sometimes quite a while before we realize just what the trouble is. The only practical method that can be used to detect these inaudible oscillations is to place a milliammeter in the plate circuit of the tube of the suspected circuit. After plugging in this meter into the plate circuit, the input to the tube is short-circuited (if a transformer-coupled amplifier is used, a load would be connected between the G post and the F post on the transformer) and no change should take place in the reading of the milliammeter. If the milliammeter shows a change in the reading does occur, it is a fairly good indication that the circuit is oscillating. During this test, no signals whatsoever should be received.

The final point at which distortion may occur is in the reproducing device, in order to obtain best reproduction from a cone speaker. It is necessary to use a semi-power rate in the output stage, with sufficient voltage to prevent overloading. It is also essential that the impedance of the output loudspeaker be closely matched with the impedance of the output transformer. If any discrepancy between the two impedances does exist, the loudspeaker should be preferably of a lower impedance than the transformer.

No. 32  RADIO BROADCAST Laboratory Information Sheet

Matching Tube and Loud Speaker Impedances

The Use of an Output Transformer

Many recent articles dealing with quality amplifiers have pointed out the fact that a loudspeaker should be connected to a transformer, or an output tube, with the impedance of the loudspeaker. This fact is important, from the standpoint of quality and, secondly, from the standpoint of efficiency, as well.

Regarding the first point, if a low-impedance cone speaker is used with a high-impedance tube, such as the 200-A, the tube drive will be lost and undue prominence will be given to the high frequencies. In order to eliminate this, one would have to use a low-impedance tube, and at the same time make it possible to obtain a considerably greater number of tubes than would be the case with the 112 and 171 tubes that have been developed; both of these tubes are high-impedance tubes. The characteristics of these two tubes were printed on the cover, and the tube manufacturer has now, No. 7 and 12, respectively. By the by, each of the 7 tubes, the frequency distortion (percent of power output tube is used) is practically eliminated.

When we use a low-impedance tube and thereby better the quality output of our receiver, we at the same time increase the efficiency with which the power developed by the tube is delivered to the loud speaker. Maximum power will be delivered to the output when its impedance is equal to the tube impedance, so that, for best results, the loud speaker impedance at a medium frequency, say 1,000 cycles, should match fairly well the output impedance of the tube.

A simple method whereby tubes and loud speakers of different impedances may be used together, is by the inclusion in the circuit of a suitable output transformer, several of which are now on the market. When a circuit is resorted to, it is necessary for the transformer to approximate match that of the loudspeaker. In this way, it becomes possible to use a low-impedance speaker with a high-impedance tube, although it is not particularly advisable since the high-impedance tubes are not capable of handling any great amount of power and will very likely overheat, if they are used to supply a loud speaker of a semi-power tube is used in the output, it is not generally advisable to connect the loud speaker directly into the plate circuit of the tube, when this is done, the plate current will pass through the loud speaker windings and will harm the magnets used in the loud-speaker unit. In order to eliminate the d. c. from the loud speaker windings, either an output transformer or a combination of a choke and condenser should be used.

No. 33  RADIO BROADCAST Laboratory Information Sheet

Tandem Tuning

Equalizing the Circuits

Tandem tuning of condensers, to decrease the number of separate controls, has become quite common. There are some fundamental facts concerning tandem tuning which must be considered if satisfactory results are to be obtained.

The output and input characteristics in which the tuned circuits work must be the same in each stage. In A of the accompanying diagram, the tuned circuit No. 2 works out of the plate circuit of one tube and into the grid circuit of the following tube. The same thing is true of circuit No. 3. Therefore, if the coils and condensers are exactly similar, the two condensers in these circuits may be coupled together and operated from a single control. The tuned circuit No. 1, however, is coupled to an antenna, and for this reason its condenser will not tune in the other two condensers and, therefore, it cannot be "ganged" with the other two circuits even though the coils and condenser have the same characteristics.

The condenser which will permit the ganging of any three condensers is shown in B. Here, tuned circuit No. 1 has been coupled to the plate circuit of an additional tube. It is now similar to the other two tuned circuits, and the three can be used together.

It is, of course, possible to so construct circuit A so as to permit ganging of all three units without an additional tube. It would require, however, very accurate cutting of the condenser plates so as to compensate any effect of the antenna circuit. This is a difficult job and it is preferable to retain two controls or to use an extra tube.

Many so-called single-control receivers are equipped with some compensating device which permits exact tuning of each circuit to resonance. In some cases this device consists of a small midget condenser connected in parallel with one of the main tuning condensers. It is placed on the other side of the stationary plates of one of the condensers mounted on a pivot, so as to permit coarse tuning without affecting the tuned circuits. Of course, during no receiver that has such an adjustable feature can accurately be called a single-control set.

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No. 34  RADIO BROADCAST Laboratory Information Sheet
Series Connection of Filaments

BIAS FROM VOLTAGE DROP

ALTHOUGH the practice of connecting filaments in series has been common in telephone work for some time, it has only lately come into use in radio work also.

When filaments are in parallel, the battery voltage must be the voltage that one tube requires. For a 225-A type tube this is five volts. When the tubes are in series the battery voltage must be the sum of the voltages, that is, for five 225-A type tubes, 25 volts is required. In the parallel case, the total current is the sum of the current taken by each tube; in the series case, the current that is taken by one of the tubes.

There are four 199 tubes in series with a 12-volt battery which furnishes 1.5 volts. There is a three-volt drop in each filament and, therefore, the positive end of the battery, the total drop increases in three-volt steps. This voltage drop can be used as a negative bias for amplifier tubes. It is only necessary to connect the grid return of the amplifier in question to the place along the line where the voltage—generally with respect to the negative side of the amplifier filament—is sufficient for proper bias.

For example, in the diagram, tube No. 1 has its grid return connected to the negative side of the filament. This represents zero bias. Tube No. 2 is also connected to the same place, but between the negative side of the filament of tube No. 2 and the point where its grid return is connected, is a three-volt drop caused by the preceding tube. In the same manner, tube No. 3 has its grid biased positively three volts since in this case there is a three-volt difference of voltage between the positive and negative sides of this filament. Tube No. 4 has a negative bias of 9 volts between its negative filament lead and the point where its grid return is connected is the voltage drop caused by three preceding tubes. In the diagram, X represents grid volts. In the article entitled "A C. B. C. Line-Voltage Detector" (February, 1935) Radio Broadcast, diagrams are given of receivers with filaments in series.

No. 35  RADIO BROADCAST Laboratory Information Sheet
Radio Frequency Transformers

TUNED AND UNTUNED

Radio frequency transformers are classified as "tuned" or "untuned." A tuned transformer is one that is to be amplified. Thus, for a particular setting of the condensers it would be great for a narrow band of frequencies but negligible for frequencies except very close to the tuned frequencies. Untuned transformers, despite the fact that they are called"tuned," may be used at any frequencies. However, they are supposed to work over a wide range of frequencies. The wide range is due to the fact that resistance or, if iron cores are used, by a combination of the advantage of the iron core. In the effective resistance introduced into the transformer by the losses that occur in iron at high frequencies. In general, it may be said that, where there is much resistance or anything else than iron in the transformer losses, the amplification will be less than that theoretically obtainable by the use of tuned transformers. A stage of tuned transformer-coupled amplification have the advantage of gain, that is, amplifying only one frequency (strictly speaking, only a very narrow band of frequencies) but have the disadvantage that as each stage must be carefully tuned, it is complicated to change from one frequency to another and difficult to pick up weak signals unless the proper setting for each tuning condenser is known in advance. In the super-heterodyne system, this disadvantage disappears because the intermediate-frequency amplification is done at a fixed frequency, irrespective of the wavelength of the station being received. The diagram shows a simple unbalanced transformer-coupled amplifier with fixed grid and plate voltages and meter stabilization. The transformers are marked Ti, T2, and T3. Receiving sets of this type are not very selective as there is only one tuned circuit to do the selecting; but they are not so temperamental as the tuning condenser and the potentiometer as are the other, and there is a wide choice of arrangements for plugging in different transformers and potentiometers, the range over which best amplification is obtained is usually only about two hundred cycles.

No. 36  RADIO BROADCAST Laboratory Information Sheet
The Super-Heterodyne

ACTIONS AND PRINCIPLES

ESSENTIALLY, the super-heterodyne consists of a receiver constructed to receive on one single frequency (however, there is a most efficient way to work), ahead of which is a frequency changing device, in combination with a detector tube (known as the super-heterodyne tuned transformer) designed to change the frequency of the incoming signals to that of the fixed current frequency. The receiver designed to receive on one single frequency consists of several r. f. stages (known as the intermediate-frequency amplifier), a detector (the second detector), and the usual audio amplifier.

The tuning is usually the element of two variable condensers, one to tune the loop to receive the incoming signals (which are passed to the grid of the first detector), and the second to tune the frequency changing device (known as the local oscillator).

It is a well-known fact that two frequencies, if superimposed, will produce a third frequency, its value equaling the difference between the two superimposed frequencies. The object of the local oscillator is to produce locally a frequency which may be superimposed upon the incoming frequency. The frequency of the locally generated wave must be such that when it heterodynes (is superimposed) with the incoming signal, the third frequency will be equal that which is capacitive and received by the fixed frequency unit of the super-heterodyne. This third frequency may be 10 kc. Thus we hear two frequencies, that mean by a common interaction and which are, by the way, slightly in pitch. This is caused by two frequencies being arrived at them from their alighted frequencies and heterodyning with other, thereby producing the third frequency. This is known as "beating." The third frequency produced by the heterodyne action in such a receiver is known as a "beat" note.

The accompanying diagram makes clear the sequence of units in the super-heterodyne. In some receivers of this pattern, a clipping amplifier is required to reduce the first frequency and frequency changing circuit. Further details of the super-heterodyne appear on Sheet No. 41.
No. 37 Radio Broadcast Laboratory Information Sheet

Single Side Band Transmission

A SIMPLE EXPLANATION

The carrier wave plays an important role in the transmission and reception of broadcasts. It is required only for the purpose of modulation at the transmitting station and demodulation at the receiving end. For actual transmission, however, the carrier need be of much smaller amplitude than the upper side of the band, and the phase will be such that the carrier is aligned 90 degrees in the carrier's own sense. The modulated carrier wave, therefore, consists of a direct current plus a series of alternating currents of the same frequency as that of the modulating current.

THE BALANCED MODULATOR

The modulated carrier wave, used to give the desired rhythm of the broadcast, may be obtained in one of several ways. As a practical matter, the modulated carrier wave is usually obtained in the transmitter by means of a balanced or divided modulator. The modulated carrier wave is shown in the diagram. Analysis of this circuit (which consists merely of two tubes, each acting as an oscillator) shows that the side bands are generated by each tube and added in the antenna, but the carrier frequency remains in the plate circuits of the one tube just circuits the effect of the carrier current in the other tube, as far as producing current in the antenna is concerned.

With power wasted transmitting the carrier, for most purposes it is best to do so because it is difficult to make the local oscillator at the receiving station exactly the same frequency. An advantage in suppressing the carrier is that the locally generated carrier frequency at the receiving end is not subject to variations in strength, and hence there is a reduction in the amount of fading of the received signal.

Furthermore, only one of the side bands is required for musical usage, and therefore, the channel required will only be one half as wide, which is an important feature if the ether is crowded with transmitting stations. Also, the receiving set can be made to receive only one half of a band of frequencies and hence offers only one half as much chance for interference to get in. If both the carrier and one side band are suppressed, the local oscillator at the receiving end can be as much as fifty cycles different, in frequency from the original carrier without serious interference with intelligibility of speech. However, the harmonic content in music would suffer. For the reasons mentioned above, the American Telephone and Telegraph Company is using single side band transmission in its transatlantic telephony tests. This system is not now practicable for short wave work, as it is too hard to "filter out" the side band that is not wanted when the width of the bands is only a small fraction of the carrier frequency.

No. 38 Radio Broadcast Laboratory Information Sheet

Neutralization

WHAT IT ACCOMPLISHES

The best way to prevent oscillation in an r.f. tuned circuit is by destroying any voltage differences in the grid and plate circuits. This can be accomplished by using three plates in the circuit (for example, by tuning a secondary circuit coupled in any way to the plate circuit), oscillation will take place.

There are a few natural methods that can be used to increase the neutralizing action in a circuit, but the most effective is to add a capacitor in circuit from the plate to the filament. This produces an alternating potential difference between grid and filament due to the resistance of the grid circuit. The result is a current flowing through the filament, and hence in the plate circuit.

In every case, the current flowing through the grid circuit causes the filament to heat up, thus reducing the capacity of the grid circuit, and thus the oscillations will cease.

In general, the neutralizing condenser will be placed in series with the grid circuit. Neutralizing is accomplished by putting a condenser across either the primary or secondary of a transformer, or across the grid and filament wires of a triode. Neutralization is commonly used in the manufacture of radios.

No. 39 Radio Broadcast Laboratory Information Sheet

Field Intensity Measurements

HOW THEY ARE MADE

IN a recent report by the Bureau of Standards, the results of field intensity measurements of broadcasting stations are presented. The distances used were fifty miles, and will give correct results at broadcast frequencies. For greater distances than fifty miles, it gives approximately the "instantaneous value of field intensity (not the average value), reached by waves subject to fading." Each point of the method makes use of what is termed the radiation constant. This constant is determined by making field intensity measurements at not less than five points distributed fairly evenly in the plane of reception at distances of about ten miles. The radiation constant is then graphically obtained and entered on the chart, in millivolts per mile. The radiation constants of several stations are given below:

<table>
<thead>
<tr>
<th>STATION</th>
<th>RATED POWER</th>
<th>DISTANCE FROM STATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>KDKK</td>
<td>120 kW</td>
<td>50 miles</td>
</tr>
<tr>
<td>WBBF</td>
<td>100 kW</td>
<td>50 miles</td>
</tr>
<tr>
<td>WAFB</td>
<td>0.5 kW</td>
<td>50 miles</td>
</tr>
<tr>
<td>WACF</td>
<td>0.5 kW</td>
<td>50 miles</td>
</tr>
<tr>
<td>WLJW</td>
<td>0.5 kW</td>
<td>50 miles</td>
</tr>
</tbody>
</table>

With the field intensity at ten miles known, the resultant field intensity at any other distance is given by the formula:

\[ F = R \left( \frac{100 - D}{100} \right) \]

where \( F \) is the radiation constant and \( F \) the field intensity at any other distance. This value of \( F \) neglects any ground absorption and gives correct results up to about fifty miles, as mentioned above.

To make a measurement a receiver is set up and a measuring grid placed in the field of the detector circuit. The deflection of the needle is observed when signals from the base station—the radiation constants of which are known, are being received. Then, as long as the radiation constant on which it is desired to make the test, and the deflec-
tion on rod again, the field strength can be determined by substituting in the formula given below:

\[ F = \frac{R \times D}{100} \]

where \( R \) is the resistance of the receiving antenna, and \( D \) the frequency corresponding to the transmitted signals of the station under test. \( R \) is the resistance of the receiving antenna at a frequency corresponding to the signal from the base station; \( I \), the deflection on the signal from the base station; \( I \), the deflection on the signal from the base station and \( I \) the field intensity of the base station determined by formula No. 1. The derivation of formula No. 2 will be found on Laboratory Information Sheet No. 3.

As a member of the Radio Association, you can earn $500 per hour in spare time. Earn it, install, repair, build sets, buy at wholesale, train for $3,000 to $10,000 radio positions, secure a better position, take advantage of the success-tested, money-making plans of the Association. Your membership need not cost you a cent if you act now.

Earned $500 in Spare Hours

Hundreds earning $3 an hour as "Radio Doctors"—Lyle Podlasek, Mich., has already made $500 in his spare time. Werner Eicher, N. Y., earns $50 a week spare time. F. J. Buckley, No., makes as much in spare time as he receives from the Mayor. W. E. Town, Chicago, as result of Association, secured a position at a $250 a week salary. K. O. Benning, Ia., went from clerk to owner and is now making $200 a week.

A membership in the Association starts you in business if you wish. It has increased salaries of many others. Scores of our members are now with big radio companies.

Becomes A Radio Engineer Quadruples Income

A year ago, Claude De Grave knew nothing about Radio. Today, he is on the staff of a famous radio manufacturer and an associate member of the Institute of Radio Engineers. He attributes his success to joining the Association. His income now is $500 more than when he joined.

If ambitious to become a Radio Engineer, to fit yourself for a $3,000 to $10,000 opportunity, join the Association and receive the comprehensive practical and theoretical training you need. A membership in the Association is the best thing you can do. Learn of the amazing ways the Association can help you. Write today.

ACT NOW—for No-Cost Membership

Send for details of Special Membership Plan that need not—should not—cost you a cent. Write today for our book "Your Opportunity in the Radio Industry" that will open your eyes.
For the A.C. Set Builder

The name "WESTON" on any meter you select is the highest guarantee of long life and dependable service with the lowest cost of instrument upkeep. The following three models are recommended for those having professional or technical interest in radio set construction—builders, transmitting and repairmen and all others who demand the best obtainable operating performance.

**Model 301**
- D. C. Milliammeter
- 2" diam.
- Price: $15.00

Use of Milliammeter in the Plate Circuit

For checking plate current and plate and grid voltage conditions. Low B and C battery voltages determined by direction of fluctuation of the pointer when strong d.c. fields are received. Placed in the B battery lead this instrument checks the set as a whole. It will check any one radio or audio stage when placed in the plate circuit of that stage. Price, $8.00.

**Model 499**
- Triple Range A. C. Voltmeter
- 150/60/4 volts.
- A compact, lightweight, portable instrument with red and black mottled bakelite case for testing B, C, supply and tube voltages of socket power A. C. receivers. Also made as double-range voltimeters up to 600 volts, and as single-range ammeters and milliammeters.
- Price: $13.50 to $18.50

No. 40

**Radio Broadcast Laboratory Information Sheet**

**Analysis of Detection**

**The Reason for the Grid Leak**

A method of detection commonly used makes use of a grid leak or condenser. The operation of the circuit may be roughly outlined as follows:

In the absence of incoming waves, the potential of the grid decreases that of the filament. The incoming waves cause the grid to become alternately more positive and more negative than the filament. While the grid is more negative, nothing happens, but while it is more positive it attracts negative electrons. These electrons cannot get off the grid once they are there, and the result will be a current, except via the high resistance which is called the grid leak. If, for the moment, we suppose there is no grid leak provided, we can see that a very weak signal coming in, the electrons drawn to the grid will charge it to a steady negative potential, equal to the maximum instantaneous potential of the top of the coil in the antenna circuit. This steady negative potential causes a reduction in the plate current. Even if the waves cease coming in, or their amplitude is diminished, the grid retains its negative charge since there is no way for the electrons to get off it. So we put in a very high-resistance leak, so high that any signal they may allow (compared to the wave frequency) escape so that, if the amplitude of the incoming waves slowly (i.e., at voice frequency) diminishes, electrons will leak off until the grid potential drops to the new maximum value of potential at the upper end of the coil. In this system the strength of incoming waves is less the plate current.

The connection shown in the diagram are often recommended.

The size of the grid leak is more or less important. If its resistance is too great, it is possible for the grid of the tube to lock on strong signals, whereas if the grid leak resistance is too low, the signal strength will be decreased. For the ordinary 201-A type tube, a grid leak of about four megohms resistance would be recommended. If a subdetector tube is used, a somewhat lower resistance leak is generally about one half to two megohms being about right.

No. 41

**Radio Broadcast Laboratory Information Sheet**

**The Super-Heterodyne**

**Intermediate-Frequency Amplifier**

In the super-heterodyne there is a group of apparatus termed the intermediate-frequency amplifier which functions to improve the best note produced by the action of the first detector and local oscillator (the Radio Laboratory Sheet No. 36). Characteristics which a good intermediate-frequency amplifier must possess are discussed below. In the first place, all of the transformers used in the amplifier must be resonant at the same frequency. Improperly matched transformers have a cause of poor operation of a super-heterodyne, since the overall efficiency of the entire receiver can be considerably lowered if one of the transformers is slightly different in characteristics from the others. Matching of the transformers is no easy process since the matching must usually be done with very low voltages in order to make the conditions similar in every way to those found during ordinary operation.

The resonant frequency must be sufficiently broad so that all side bands which make up the signal are evenly amplified. On the other hand, if the resonant curve is too broad, the selectivity of the system will not be good enough. No trouble should be met with in regards selectivity in the intermediate amplifier when properly matched air-core transformers are used, but these must be carefully designed to prevent some of the side bands being cut off, due to their (the transformers') sharp peaks. Iron-core transformers are often used in super-heterodynes in conjunction with a filter. Since the selectivity obtained from the iron-core transformer is not great enough, it is necessary to improve this characteristic by placing, either before or after the amplifier, a tuned circuit, known as the filter, designed to pass only those frequencies for which some of the transformers give the maximum amplification. Regeneration in the intermediate-frequency amplifier will considerably improve the selectivity and sensitivity by sharpening the resonance curves of the transformers.

The common method of connecting together inductor and transformer amplifiers is illustrated in the diagram, in which potentiometer control of regeneration is used.

No. 42

**Radio Broadcast Laboratory Information Sheet**

**Super-Regeneration**

The theory explained

Where lead signals are required from a loop, and the number of tubes is limited to one or two, super-regeneration can be used. Super-regenerative circuits are not as selective and hence are not very good for working through interference. The principle of super-regeneration is explained simply by a mechanical analogy. Suppose a clock to be wound up and the pendulum placed carefully in its lowest position and left there. The clock will start itself. But now, suppose strong puffs of air come along at the proper interval to stop the pendulum and start it again. If the puffs of air stop coming in at the pendulum "build-up" and in due time the amplitude of swing reaches a limit fixed by the pendulum, air resistance, etc. But if we confine our attention to a sufficiently short period of time after the swing starts to build up, we shall find the amplitude attained during this time is proportional to the strength of the incoming puffs made in the interval described. Let the pendulum be stopped and set again at its lowest point so that the whole operation may be repeated. A great deal more swinging is done by the pendulum if the clock is wound up and the puffs of air are playing on it, than if the clock were not wound up, in which case the pendulum would only swing the very small amount caused by the air puffs.

In the electrical sense, in super-regeneration, we have a circuit all set to oscillate, i.e., wound up and balanced, so to speak, so that some incoming signal is required to start oscillation. This is similar to our analogy, in which the puff of air is necessary in order to keep our pendulum swinging. In the super-regenerative receiver, the oscillations started by the incoming waves are permitted to build up very rapidly in the same manner that they would be built up in an ordinary regenerative receiver if the coupling was greatly increased beyond that necessary to make the detector oscillate. However, before the circuit can break into continuous oscillation, the existing oscillation is automatically extinguished by another oscillation (generally about 10,000 cycles) which opposes the incoming oscillations over 20,000 cycles of a second. This 10,000-cycle oscillation may either be generated in the same tube or another tube coupled to the detector. The 10,000-cycle oscillation is, every 20,000 cycles of a second, the 10,000-cycle oscillation has no effect upon the incoming signal and during this half of the cycle it is used to prevent the production of any high frequency oscillation in the detector circuit.

Consequently the signal energy is very large during half of each 10,000-cycle oscillation, and on the whole there is very much more energy in the detector grid circuit than would be present under ordinary conditions. A comparatively large voltage is therefore impressed on the grid, which makes a correspondingly larger amount of energy available in the plate circuit.
Field Intensity Measurements

Determination of the Formula

On Laboratory Sheet No. 39 were given some data regarding the measurement of the field intensity of broadcasting stations. Further information concerning this subject is given on this sheet, with regard, especially, to the derivation of the formula which was given on the previous Laboratory Sheet.

With the field intensity of some base station known, from actual measurements at a distance of ten miles, it is possible to calculate the field intensity of the base station at any other distance up to about fifty miles, by the formula given below:

\[ P_f = \frac{P_0}{d^2} \]

Where \( P_0 \) = field intensity of base station at distance \( d \); \( d \) = distance from station in miles; \( P_0 \) = radiation constant of base station.

The field intensity, \( P \), of the station under test, is determined by the relative deflections of a meter in the plate circuit of the detector tube when signals from the base station are being received and when signals from the test station are being received.

To determine the field intensities, the following formula is used:

\[ P = \frac{P_0}{d^2} \]

Where \( P \) = field intensity of station under test; \( d \) = distance from the antenna of the test station to the antenna of the base station.

With the field intensities known, the relative intensities of the signals from the base and test stations may be calculated.

Volume Controls and Voltage Controls

Volume controls are now conceded by radio engineers to be one of the most essential parts of radio receivers. So much of the success of a set—the quality of reception—is dependent upon them.

Centralab Volume Controls assure absolute smoothness of control—a big factor in satisfactory operation. This smoothness of Centralab Controls results from the tiling disc construction — with no sliding contacts in the electric circuit.

A Centralab Volume Control, in one of the many new tappers, is ideal for any set. Many prominent manufacturers specify them. They are in demand, also, for replacement on old sets.

Centralab Wire-Wound Resistors will give better voltage-regulation of Power-supply units. Their construction is heat-proof and warp-proof and provides for greater current carrying capacity. The Centralab Heavy-duty Potentiometers have an additional feature—they are non-inductive.

Write for complete descriptions, prices, etc., of Centralab Volume Controls and other radio devices.
AEROKITS
for Building
Broadcast Receivers

Aero Broadcast Receiver Kits are supplied complete to the last detail. Beautiful twotone metal cabinets, high-lighted with silver, set off a handsome cathode plate of oxidized silver, beautifully etched with the name of the receiver. Handsome walnut finished knobs control tuning and volume controls, and the foundation units include every machine screw, piece of wire and direct wire soldering necessary for the construction of the receiver, leaving nothing whatever additional to be purchased.

No expense has been spared to make each kit the finest of its type. The coils are especially designed for the service to which they are put. An illuminated microphone dial insures easy tuning. Audio frequency transformers of a type heretofore used only in broadcast station line amplifiers. Each Aero Receiver is far superior to the finest factory built set available anywhere at near same price.

AERO-SEVEN
TWENTY-NINE
SEVEN-TUBE SET

A de Luxe Receiver, even better than last year's "Aero Seven" which was deservedly so popular. This set under normal conditions has an easy range of two thousand miles or more, and its fidelity of reception is truly surprising. Four tuned stages assure selectivity. The complete foundation unit makes construction easy.

Aero complete kit No. 32 for shield grid tubes, No. 33 for A.C. tubes, No. 34 for D.C. tubes. Price each $7.85.

Aero complete kit No. 32-P for shield grid tubes and No. 34-P for D.C. tubes. No cabinet, but drilled panel included. Price each $8.75.

Aero
"CHRONOPHASE"

A Five-Tube Receiver, in which the inclusion of the "Chronophage" R.F. Amplifier produces unusual selectivity. Extremely easy to build, and sure to give excellent results. The actual size of the wiring diagram makes mistakes very rare.

Aero complete kit No. 20 for shield grid tubes, No. 21 for A.C. tubes, No. 22 for D.C. tubes. Cabinet included. Price each $7.50.

Aero complete kit No. 20-P for shield grid tubes, No. 21-P for A.C. tubes, No. 22-P for D.C. tubes. No cabinet, but drilled panel included. Price each $8.55.

OTHER KITS

The Aero-Dyne, a six-tube set, the Metroglobe, a four-tube receiver, and the Aero Trio, a three-tube set, are other new Aero receivers of remarkable range, selectivity and tone purity. Kits are complete and large schematics and pictorial wiring diagrams make building easy. Ask your dealer or write direct to us.

Send for the New 1929 Aero Green Book
Sixty-four pages of useful information

AERO PRODUCTS INCORPORATED
4611 Ravenswood Ave. Chicago, Ill.

No. 46
RADIO BROADCAST Laboratory Information Sheet

 Loud Speakers

SOME GENERAL CONSIDERATIONS

It is easy enough to fix a megaphone to a telephone receiver to produce a loud signal, and some loud speakers are merely refinements of this idea. The horn concentrates the sound in one direction, and the tapered column of air within the horn that fills the space about the small receiver diaphragm at the small end, and swells gradually out to join the open air at the flared end, supplies something for the diaphragm to work against. The diaphragm is caused to set more air in motion just as if a larger diaphragm were used, thus increasing the volume of sound produced. But the cues are much as the best reproducers are only about 2 per cent. efficient (that is, 100 units of electrical energy entering them only about 2 leave in the form of sound energy), only small efficiencies are likely to be obtained even when good horns are coupled to the diaphragm. The great sensitivity of the human ear helps to make up for the inefficiency with which energy is converted from mechanical to acoustical by means of vibrating diaphragm bodies. In ordinary speech only about one ear (the ear is the voice box's unit of energy) per second is converted into sound energy. How little this is can be seen from the following calculation: Reckoning that the average human being talks the equivalent of two hours daily talking per day, and that the average population of the United States since the Revolution is forty millions, and that power is worth two cents per kilowatt hour, then, from the energy point of view, all the talking that has been done in the history of our country is only worth 86.6! In addition to the low efficiency of the conventional loud speaker, several other objections are raised. One is the method of masking radio signals audible by the horn. Another is the low degree of misgiving this is by the use of two or three separate horns, each with its own dedicated microphone. In the case where three are used, for example, one is a very long horn that requires an echo in low zones; the second is an ordinary unused loud speaker responding fairly well over a broad range; and the third is a very small horn giving the very high-pitched notes. The three horns, all working at once, combine to give a satisfactory uniform response over the whole audible range. The three horns, of course, are combined in a single box. The long horn can be cleft to save space, if necessary.

Another type of loud speaker avoids such disturbance as is due to the horn by using no horn at all. This type of speaker usually, but not necessarily, has a large, light, stiff paper cone for a diaphragm, and this cone is sufficiently firm to give a good "grit" on the air. At present only a few commercial types exist, and a great many of them are in various stages of development. The goal of quality, which is to have all frequencies transmitted from speaker to listener with equal efficiency.

No. 49
RADIO BROADCAST Laboratory Information Sheet

Trickle Chargers

DIFFERENT TYPES AVAILABLE

It has been customary in general to operate a radio receiver from a storage battery having a capacity large enough to supply the receiver for the entire year or so there has come into rather common use the combination of a storage battery with a trickle charger. This combination consists of a small storage battery, and a low voltage direct current device called the trickle charger. The trickle charger connected to the storage battery, serves to keep the battery in a constantly charged condition.

There are several types of rectifiers which have been used in trickle chargers. In the tube type of rectifier, which we are all familiar, a small vacuum tube is used which rectifies the alternating current and supplies it to the battery. The rise of this type is more familiarly known as the Tungsten or Rectifier tube, and is very satisfactory and dependable.

The second form of rectifier is the electrolyte type which is composed of cells suspended in a salt electrolyte. It is very simple to construct and works very satisfactorily. It is probably more efficient than the above type since it does not require any energy to light a filament. The third type, which has only recently come into prominence, uses a crystal. We are all familiar with the crystal detector used in a radio receiver which functions to rectify the radio frequency signals, and since the trickle charger need only supply a small current it seems quite possible to use a number of crystals. Depending on the specific models using this system are now on the market. A battery of small size will be sufficient and, in this way preparation is made for any emergencies that might occur.

When the storage battery is operated in conjunction with a trickle charger the only attention required is to keep the battery in the box. It is wise to test the battery periodically by connecting it to a shunt and observing the current indicated. It is also advisable to keep the trickle charger always charged. If the trickle charger is always charged the battery will be in a better condition. If the trickle charger is not always charged the battery will be in a better condition. When a battery is kept in good working order it may be possible to operate the receiver for several days without charging and in this way preparation is made for any emergencies that might occur.

Another type of trickle charger is of the hydrum type, which is composed of a number of cells connected in series and each a number of plates. This type of charger is much more expensive and is not generally used in practice.

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### No. 50

**RADIO BROADCAST Laboratory Information Sheet**

**Hard and Soft Vacuum Tubes**

<table>
<thead>
<tr>
<th>No. 201-a tubes</th>
<th>effects, connected when ionized filament depends on the gas.</th>
<th>Tube connected, the only difference being that they have no gas content. Amplifier tubes do not require any critical adjustment and will operate on from 40 volts up to the maximum that can safely be placed on the tube. A diagram of connections of a 200-a detector tube is given here.</th>
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<tr>
<td>No. 201-b tubes</td>
<td>effects, connected when ionized filament depends on the gas.</td>
<td>Tube connected, the only difference being that they have no gas content. Amplifier tubes do not require any critical adjustment and will operate on from 40 volts up to the maximum that can safely be placed on the tube. A diagram of connections of a 200-a detector tube is given here.</td>
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### No. 51

**RADIO BROADCAST Laboratory Information Sheet**

**Overtones (Harmonics)**

**THER IMPORTANCE IN RADIO**

A GREAT many of the fundamental notes used in A.C. receivers are harmonics which determine the quality and timbre of the sound. In order to obtain perfect sound, the harmonics of all the amplifiers and reproducers used in a radio receiver must be absolutely flat, i.e., they must transmit all frequencies with equal fidelity. Two sets were mentioned above as harmonics which are produced by all instruments, including the human voice, and the correct transmission of the harmonic frequencies is essential if the characteristic frequencies of the original sound are to be maintained. In many cases it is the prominence of certain harmonics which distinguish the different instruments from others. Quite frequently overtones are confused with the harmonics and there is a difference between these two units. The fundamental sound of say, 500 cycles has one octave at 100 cycles, another octave at 2000 cycles and another one at 4000 cycles, etc. Each octave being double in frequency to the one preceding it. If two octaves are sounded at the same time, it is rather difficult to distinguish between them. On the other hand, the fundamental note of 500 cycles has overtones, or harmonics, corresponding to 1000, 1500, 2000, 2500 cycles, etc. In this case, the various tones are separated by half an octave or amount equal to the fundamental frequency. Whereas the difference between two octaves is rather difficult to detect, it is quite easy to distinguish between various overtones. From the above, it is evident that some octaves are more evident than others. Of course, the octave at 1000 cycles corresponds to the 2nd overtone of the fundamental 500 cycles. However, the next overtone is 1500 cycles, but there is no octave corresponding to this pitch. It is evident that, starting with a certain note, all octaves correspond to certain overtones but that all overtones are not octaves. On Laboratory Sheet No. 52 there is reproduced a diagram showing the fundamental frequency range of various instruments. In the diagram given, it will be noted that an extra octave is shown at the high frequency end of the piano keyboard. As experience has shown that at least one harmonic must be provided for when amplifying a signal near the top of the audible frequency scale, to obtain true fidelity, the extra octave is included to indicate the frequency range requirements of an amplifier to successfully reproduce the highest note of the piano, which has a fundamental of 4960 cycles.
SANGAMO
Mica Condensers

Are accurate—Stay accurate
Guaranteed to be within 10% of rated capacity

SANGAMO Mica Condensers are absolutely waterproof and unaffected by dampness or the salt air of the sea, which has a corrosive effect on exposed condensers. Sustained accuracy in fixed condensers is of the utmost importance. These condensers are as finely made and as handsomely finished as the most costly radio parts and harmonize perfectly with beautiful workmanship. The rounded edges and high rib give them great mechanical strength and insure constancy of adjustment.

SANGAMO
Quality Audio Transformers

Two complete lines of audio transformers have been developed by the Sangamo Electric Company, and in each line units will be found to match the impedance of any of the power tubes now on the market with the impedance of any of the loud speakers now available. The standard "A" line is well known and needs no additional description. The new "X" line has just been developed in the Sangamo laboratories, and these instruments are now being manufactured to meet the great demand for a unit of this type. The amplification curve and general characteristics of the "X" line are very similar to that of the "A" line, with the exception that the low frequency end of the amplification curve is somewhat lower than the straight line amplification curve of the "A" units.

Write for prices and further description of Mica Condensers and Audio Transformers.

SANGAMO ELECTRIC COMPANY
Springfield Illinois

No. 52
RADIO BROADCAST Laboratory Information Sheet

Frequency Ranges of Musical Instruments

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No. 53
RADIO BROADCAST Laboratory Information Sheet

Shunts

Determining Their Value

SHUNTS, as used in an electrical laboratory, consist of an electrical conductor placed in parallel with an indicating meter so as to increase the range of currents that can be read with this meter. We might have a 10-milliampere meter and desire to read a current of, say, 50 milliamperes; with the aid of a shunt, this can easily be done. The method of calibrating a shunt is indicated in the diagram.

Suppose we desire to calibrate a 10-milliampere meter so that it will read 50 milliamperes. We would connect a battery, B, as indicated on the diagram, in series with a variable resistance, V.R., so as to limit the current passing through the meter (without a shunt) to 10 milliamperes. The resistance would be varied until the meter read exactly 10 milliamperes and then the rheostat (R) (the shunt) would be switched across the meter and its resistance altered until the meter read two milliamperes. Under such conditions with the shunt connected, a reading of 2 milliamperes on the meter would mean that 10 milliamperes were flowing through the circuit. Likewise, full scale deflection would indicate a 50-milliampere flow although the needle pointed only to 10 milliamperes. The same procedure would be followed in calibrating any instrument, i.e., setting up a circuit which will pass sufficient current to give a maximum deflection on the meter, then shunt the meter and read at a definite amount such as one half, one third, or one fifth, etc., in order to determine the actual current flowing in the circuit with the shunt connected, it is merely necessary to multiply the meter reading by 2, 3, or 5, depending upon how much the original deflection of the meter was reduced by the shunt.

No. 54
RADIO BROADCAST Laboratory Information Sheet

C Battery Detector

Form of Plate Current

In this Laboratory Sheet we are going to discuss some points regarding the operation of a C battery type detector. We are going to consider, in particular, the form of the plate current of this detector tube.

When no signals are being received, the plate current is constant and depends on the adjustment of the C battery. For best operation of a detector of this type, about four volts of C battery should be used on the 200-A when 45 volts are used on the plate. When a signal is received, the plate current varies and is then made up of two components; one of these components is the pure d.c. current that flows in the plate circuit when no signals are being received. The other component is an alternating current which is produced by the audio frequency modulating in the carrier waves that are being received. Although the detector is a rectifier, the current in the plate circuit is not in the form of a pulsating current as might be obtained from such a unit as a Walter type device, which is also a rectifier.

When the signal is being received, the voltage is impressed across the input and the accompanying diagram. This voltage causes the grid to become alternately more positive and then negative with respect to the plate due to the C battery. However, the C battery voltage is such that a grid change of plate current takes place when the grid becomes more positive. Therefore, the current variations in the plate circuit increase more than they decrease and the result is that the average current in the plate circuit is higher than when no signal is being received. These current variations in the plate circuit can be detected if they are permitted to pass through a telephone. Also, if a transformer primary is placed in the plate circuit, the current variations will produce a varying flux in the core and will cause corresponding voltages in the transformer secondary, and these, in turn, can be impressed on a further tube and the signal amplified.
No. 55
Radio Broadcast Laboratory Information Sheet
Tuning the Antenna Circuit

In Practice, all receivers described 20-day no tuning is needed in the antenna circuit. Generally the antenna circuit is of fairly high resistance and inductance and, consequently, it is seldom worth while to accurately tune this circuit. However, some increase in signal strength can be obtained by approximately tuning the circuit to resonance. This tuning can be accomplished in several ways. The simplest method is to use a Variac as shown in sketch A. The taps should be so designed that the antenna circuit is in parallel with approximately 160 kilohms when the fewest number of turns are included in the circuit, and at least at about 500 kilohms when the total number of turns are in the circuit.

The antenna circuit may also be tuned with a variable condenser, as shown in B. The variable condenser must be capable of being varied in inductance sufficiently to cover the desired band of frequencies.

The disadvantage of tuning the antenna circuit is that it adds another control when the trend in design is toward the elimination of controls. Evidence, therefore, the solution is to design an antenna tuning device that can be automatically controlled, perhaps by attaching it to the shaft of the variable condenser, as is done in the "Equimatic" system, to vary the coupling of coils between tubes in an r.f. amplifier.

No. 56
Radio Telegraph Transmission

Different Types of Waves

In Transmission work by telegraph there are six different types of waves used, each being illustrated in the accompanying drawing. The drawing A represents the type of wave radiated by a spark transmitter. This form of wave is known as a damped wave since it gradually decreases in amplitude. One of these wave trains is radiated each time that a spark takes place between the electrodes of the spark transmitter. Generally, the spark frequency is about 600 per second, so that if the transmitter was turned on there would be 500 of these wave trains radiated per second. This type of transmitter is gradually replaced by apparatus using vacuum tubes for the generation of the high-frequency oscillations.

The second form of radiated energy is illustrated in B, and is known as an L. C. V., meaning Interrupted Continuous Wave. In this system, the energy is radiated in a series of wave trains similar to the radio waves obtained from a spark transmitter, the difference being that the amplitude of the radiated wave is constant and does not decrease as shown in A.

Energy of this form could be obtained by supplying a transmitter from a plate battery in series with which there was arranged some form of interrupter which opened the circuit, say, 500 times per second.

The third type of transmitted wave is known as C. W. or Continuous Wave and in this system energy is radiated all the time that the key is pressed and it is not cut off as was shown in the two instances given above. This form of transmission is a very common one and is used by the majority of the high-powered transmitter stations and in amateur work.

No. 57
Radio Broadcast Laboratory Information Sheet
What is Resonance?

An Electrical Analysis

It has frequently been said that, in order to receive any particular station, we must tune the receiving circuit of our receiver to resonance with the incoming frequency. We shall endeavor, in this sheet, to explain what is meant by resonance.

In the accompanying sketch, first refer to "A." A diagram, shown in simple circuit, consisting of some source of alternating voltage, marked E, in series with the reactance or impedance offered by the condenser to the flow of current depends upon the time period, or frequency, of the alternating current. As the frequency increases, the reactance of the condenser decreases, and the curve approaches the zero axis. Capacitive reactance is usually considered negative, as shown, in order to indicate that it is opposite in effect to the inductive reactance.

If, as indicated in the circuits are replaced by a coil or wire, or inductance, as shown in No. 2, "A." we find that the inductive reactance increases with an increase in frequency. Frequency is shown by the curve marked L on "B." Now, if we connect both a condenser and an inductance in a circuit as shown in No. 3, "A," we will have a combination of the effects produced by both of them. Remembering that the effective reactances or impedances are opposite in sign, we may add the two curves together and the result will be a curve such as that marked "Total Reactance" in "B." At one point we notice that the line passes through zero, this point being indicated by the dotted line marked R. In other words, at this point, the total reactance in the circuit is zero, the reactance which is due to the condenser cancelling out the reactance due to the inductance.

When a circuit is tuned to resonance, the capacity and inductance are so proportioned that their effects in the circuit are nullified, and, as more current will flow in a circuit of less resistance or reactance, the combination will offer very little opposition to the current having a frequency of R in the diagram, and will offer considerable resistance to any other currents having a different frequency.

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American Radio Relay League
1713 Park Street Hartford, Conn.
**No. 58**

**Radio Broadcast Laboratory Information Sheet**

**Type 171 and 210 Tubes**

**A Comparison**

Both of these tubes are suitable for use in the front stages of audio amplifiers, but under certain conditions one tube is to be preferred over the other.

By glancing at the table, it will be seen that the output resistance is lower for the 171 than for the 210 for all values of plate voltage. The greatest transfer of energy occurs between a tube and a speaker when their impedances are matched. As most loudspeakers have very little impedance at low frequencies, the output of a tube such as the 171 which has a very low plate impedance, to devices.

<table>
<thead>
<tr>
<th>TUBE</th>
<th>GRID VOLTS</th>
<th>PLATE VOLTS</th>
<th>OUTPUT RESISTANCE</th>
<th>MAXIMUM UNDISTORTED OUTPUT (MILLIWATTS)</th>
<th>AMPLIFICATION FACTOR</th>
<th>PLATE CURRENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>171</td>
<td>16.5</td>
<td>135</td>
<td>190</td>
<td>130</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>180</td>
<td>250</td>
<td>130</td>
<td>3</td>
<td>16</td>
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<tr>
<td></td>
<td>25</td>
<td>180</td>
<td>2000</td>
<td>3</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>210</td>
<td>4.5</td>
<td>90</td>
<td>900</td>
<td>1.8</td>
<td>5</td>
<td>4.5</td>
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<tr>
<td></td>
<td>9</td>
<td>135</td>
<td>8000</td>
<td>65</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>10.5</td>
<td>150</td>
<td>7400</td>
<td>60</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>250</td>
<td>5600</td>
<td>340</td>
<td>12</td>
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</tr>
<tr>
<td></td>
<td>35</td>
<td>225</td>
<td>5100</td>
<td>925</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>250</td>
<td>5000</td>
<td>1545</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

This comparison to a certain extent the low amplification factor of 2. From the figures given for the maximum undistorted output, it can be seen that with 180 volts on the plate, the 171 will deliver to the load 700 milliwatts of power. This is about the same power as can be obtained from a 210 with about 300 volts on the plate. However, at 426 volts, the 210 is capable of delivering more than twice the undistorted power of a 171. It is quite evident then, that the 171 is somewhat to be preferred when used in home, and that for unusual volumes, such as large halls, the 210 would prove more satisfactory.

**DRACTICALLY**

No. 59

**Radio Broadcast Laboratory Information Sheet**

**What Are Harmonics?**

Their electrical characteristics

Practically none of the sounds that we can hear be said to be pure, in the sense that they contain only one frequency. Several different persons could all sing the same note and yet the different voices would be easily distinguishable. A violin and a flute might play the same note, but they would sound entirely different.

The factor which causes this difference is the existence in practically all sounds of various harmonics, or overtones, about which something has been said in Laboratory Sheet No. 51. In the present sheet, we will explain, from an electrical standpoint, what harmonics are.

Aurally, the difference between a fundamental note and, say, its fifth harmonic is that the pitch of the harmonic is five times as high as the pitch of the fundamental. Electrically, the difference is that, for every time that the fundamental note goes through one cycle, the fifth harmonic goes through five cycles. This difference between a fundamental and any of its harmonics always is true, i.e., while the fundamental passes through one cycle, a harmonic passes through a number of cycles, depending upon what harmonic it is; the second harmonic passes through two cycles, the third harmonic passes through three, the fourth through four, and so on.

A cycle comprises one complete alternation of the wave and, therefore, for ordinary signal strength such as is needed in the home, and that for unusual volumes, such as large halls, the 210 would prove more satisfactory.

No. 60

**Radio Broadcast Laboratory Information Sheet**

**Filter Circuit Data**

**Condenser Values**

Some interesting data were given in the General Radio Experience of July, 1929, regarding the characteristics of filter circuits for use with B-current supply devices.

In the diagram, the condenser marked C1 may be called a reservoir condenser as its function is to store up energy during the peak of the wave and feed it back into the circuit at the lower values of the wave. This condenser is especially valuable in keeping the voltage more nearly constant with varying loads. A small condenser at this point will cause the voltage to drop very readily with increasing load.

The condenser marked C2 is placed across the output; and is especially valuable in eliminating any ripple. The curves given on this sheet indicate the effectiveness of filter condensers of normal values of condensers in the two positions. It should be noted that an increase in either one of these condensers improves the regulation (curve B and C both showing a decrease C1, both showing a decrease C1) due to increasing the size of the load. Curve C shows the best regulation where C1 is the larger. This indicates that an increase in C1 is more effective in improving the voltage regulation than C2. An oscillograph would show that an increase in either condenser would tend to eliminate the ripples but that less ripple would be obtained by increasing C2 rather than C1.

Both experiment and theory seem to indicate that, with a certain total capacity in the system, the best regulation and the least ripple are obtained by making both of the condensers of the same value.

The curves shown are for a single section filter using the Raytheon tube as a rectifier. A multi-section filter would, however, give the same type of curves.
The Intermediate Frequency Amplifier

CHOOSING THE BEST FREQUENCY

The best operating frequencies for intermediate-frequency amplifiers are 45, 50, 60, etc. rather than 40, 50, or 60 kc.

At the present time, broadcasting stations are supposed to be separated by a frequency of 10 kilocycles. Consequently it is quite possible for any two stations to be separated, by, say, 40 kilocycles. If two stations are one strong and the other weak, are separated by this amount, it may be quite difficult to completely separate them by means of a single tuned circuit such as a loop. Therefore, both of these frequencies would be present in the same circuit, and will act on each other to produce a frequency equal to the difference between their respective frequencies. That is, a station on 500 kilocycles would heterodyne a station on 460 kilocycles and produce a 40-kilocycle beat note.

Should the intermediate-frequency amplifier happen to be tuned to this frequency, both stations will be heard in the output, even though the oscillator is supposed to be cut off by the circuit. If, on the other hand, the intermediate-frequency amplifier is tuned to 45 kilocycles, only the heterodyne beat between the station wanted and the oscillator would be amplified.

We have endeavored to show this idea in the diagram where a 40-kc, intermediate amplifier is used. "A" is the interfering station, "B" is the station desired, and "C" is the wave produced by the oscillator. Curve C, "is tuned to 540 kilocycles and produces a 44-kc beat note or heterodyne with the desired signal B which is fed to the intermediate-frequency amplifier. However, at the same time, we will suppose that there is a powerful local station "D", operating on 460 kilocycles (indicated by A), and the interaction between A and B also produces a 40-kilocycle beat note. The result is that the station broadcasting on 460 kilocycles will also be amplified. When stations whose frequencies are multiples of 10 heterodyne, they naturally produce a beat note which also is a multiple of 10. In designing the intermediate amplifier for a frequency which is not divisible by 10 it would be, therefore, exclude beat notes of two heterodyning stations if such are divisible by 10. Hence the desirability of a 45-, 65-, or 85-kc, intermediate amplifier.

[Diagram of waveforms and curves indicating power output and wavelength]

No. 62

Radio Broadcast Laboratory Information Sheet

Antenna Power Dissipation

— DISTRIBUTION OF ENERGY

The power supplied by an oscillator to a transmitting antenna may be distributed in three ways:

1. By radiation, second, in the form of heat due to resistance of the wires in the circuit; this radiation can be cut off by dielectric absorption.

2. Only the first of these factors represents a useful dissipation. This radiation is the power which transmits it to the antenna in the form of electromagnetic waves (as signals). Curve A in the accompanying graph shows how the radiated power varies with the wavelength, it being proportional to the square of the current and inversely proportional to the square of the wavelength.

3. Curve B represents the power used up in the resistance of the wires. This is a straight line and does not vary with the wavelength. In actual practice, the eddy current loss and skin effect might slightly modify the lower wavelengths, but the variation is so small that it may be neglected.

Curve C illustrates the variation of wavelength of the power absorbed in the dielectric, and, since this absorption is proportional to wavelength, the curve is a straight line. This loss is due to trees, buildings, masts, or other objects in the vicinity of the antenna which absorb power.

— POWER

WAVELENGTH

D

C

B

A

Curve D represents the total power in the antenna, and is equal to the sum of the three separate curves. In taking curves such as this on an antenna, it is quite possible to obtain humps at certain wavelengths. This generally indicates the presence of some circuit in the vicinity of the antenna with a natural period of oscillation at that wavelength.

No. 63

Radio Broadcast Laboratory Information Sheet

Line Power-Supply Devices

CALCULATION OF RESISTANCE VALUES

In order to obtain four output voltages from a line power-supply device we will place four resistances, Ri, R2, R3, and R4, across the output terminals of the device.

The positive voltage tap, E, for the detector grid will be obtained from the point Ri and R4. The voltage, Ea, obtained by subtracting the voltage from R4 and R2. Voltage E, with a value of, say, 135 volts, may be expressed from a tap connected between R2 and E. L is the maximum voltage of the unit.

In order to use this information, as a resistance in a circuit, we must assume that a certain amount of current flows through the component. If the current through R2 and R4, and we desire 220 volts for the detector, then E = 125.5 volts in the 4500-ohm taps. If the voltage required is 45, then R4 = 45 + 125 = 300 ohms.

The voltage across Ri is 90 — 231 = 61 volts, and as the detector plate current at 225 volts is 1.5 ma., we find that the current across Ri is 0.005 ma. amperes, which is sufficient. The power consumed in the 300-ohm tap is 61 x 0.4 = 24.4 watts. The total power consumed is 24.4 + 300 = 324.4 watts.

To determine the current in Ri, we must know the plate current taken by each tube operating at 125 volts. The plate current in the 200-kiloamplifier is 20 ma., or 0.02 ampere. The current flowing in Ri is 0.02 x 2.25 = 0.045 amperes, which is sufficient for the detector. The total power consumed in this amplifier would be 0.045 x 300 = 13.5 watts.
No. 64

RADIO BROADCAST Laboratory Information Sheet

The Gang Condenser

Correct Connections

Since the appearance on the market of gang condensers, that is, condensers having a common shaft and working in unison, many readers have requested information as to how they should be connected. The difficulty in connecting them usually arises from the fact that all of the rotor plates are connected together, thus making it impossible to get a positive ground lead for the detector tube, while the radio frequency tubes of necessity must be negatively biased.

By looking at the diagram, it will be noticed that the filament return of the detector tube coil does not connect to the variable condenser but to the positive filament lead. A path for the radio frequency current is provided through the by-pass condenser, as shown, to the tuning condenser. An alternative way of connecting is to allow the by-pass to be connected to the condenser, making the grid positive by connecting the grid leak directly between the grid of the tube and the positive filament. The grid condenser prevents the short circuiting of the batteries.

When a gang condenser is used, the coils must be carefully matched in order to minimize any inequalities between them. In spite of careful matching, there are bound to be some discrepancies, and it is frequently necessary to use a separate condenser in the antenna circuit, as outlined in Laboratory Sheet No. 224. Some gang condensers are provided with small condensers in parallel with the main condensers, which may be used to bring each circuit into exact resonance.

No. 65

RADIO BROADCAST Laboratory Information Sheet

The Vacuum-Tube Voltmeter

How it functions

The vacuum-tube voltmeter is a very useful instrument and is found wide use in an electrical laboratory. The simpler type is not at all difficult to make up, and with it some interesting measurements can be made. For best results it should be calibrated, but even without calibration it is still possible to make many measurements with it that will give a general indication of the comparative merits of different coils, amplifiers, and other units, etc.

The circuit diagram of a vacuum-tube voltmeter is given on this sheet. The B-battery voltage need not be more than 240 volts, and the indicating instrument in the plate circuit should have a maximum scale reading of not more than 1 milliamperes. The C-battery voltage should be adjusted until the meter reads about 1/4 of a milliamperes when the terminals 1 and 2 are short-circuited.

The tube is now being operated on the lower bend of its characteristic curve, similar to the condition under which a C-battery detector operates. Now, if any voltage, whether it be direct or alternating, is impressed across the input terminals, the plate current will change. If a calibration is to be carried out, it is accomplished by impressing various known values of voltage across the input terminals and reading the corresponding deflections of the plate milliammeter. Then, if the input terminals are connected across any unknown voltage it is possible to determine the value of this voltage by noting the deflection of the plate milliammeter. The actual voltage is obtained from the previously made calibration curve.

As mentioned, even if instruments are not available with which a calibration can be made, it is possible to make comparative tests. For instance, by placing the same input on two amplifiers under test and then connecting the vacuum-tube voltmeter across the output of each, readings may be obtained. Obviously, the amplifier which produces the greatest deflection has the greatest amplification.

No. 66

RADIO BROADCAST Laboratory Information Sheet

A Radio Frequency Oscillator

Its Use and Construction

A diagram of a simple oscillator that takes all of its energy from the power mains is given on this Laboratory Sheet. A unit such as this is quite useful to the home constructor in making tests on receivers. It sends out energy in much the same way as any broadcasting station, and it can be tuned to deliver this energy at any frequency between 50 and 1500 kc. (600 and 200 meters). It makes use of a 201-A tube and will operate on either 110 volts a.c. or d.c. If the latter is used, the device will only function when terminal No. 2 is connected to the positive side of the line.

The coils, L1 and L2 may be wound on a single piece of tubing 34 inches long, having an outside diameter of 21 inches. L1 consists of 50 turns of No. 26 d.c.c. wire, and L2, spaced 1 inch from L1, consists of 40 turns of the same size wire. Both coils are wound in the same direction.

The condenser, C, should have a maximum capacity of 0.001 mfd. An ordinary electric light bulb of 25 watts rating is shown in the circuit. If by any chance the oscillator is to be used on a 250-volt circuit, the electric light bulb should be replaced by one suitable for use on this voltage, and should be rated at 50 watts.

If this oscillator is supplied with alternating current and is placed within a few feet of a receiver, it will be possible to tune in the signal generated by it if the receiver is of a high-Q type. The note heard will be a low-pitched hum. If the unit is supplied with direct current it will not be directly audible. However, if it is connected in such a way as to bring the note out to a loudspeaker it will become audible. If the oscillograph is equipped with a synchroscope, it will not be possible to produce a heterodyne whistle, when the set is tuned in.
**No. 67**  
**RADIO BROADCAST Laboratory Information Sheet**

### 171 Tube Characteristics

**PLATE IMPEDANCE**

This Laboratory Sheet will explain how to determine the plate impedance, or output resistance, of a tube by using formulae that can be obtained from the static characteristics. Specifically, it deals with the 171 tube, which has a plate impedance of 25 to 15.8 ohms, and 10.2 ma being the change in plate current. Therefore, the plate impedance of the 171 is equal to the change in plate voltage divided by the corresponding change in plate current.

To calculate the plate impedance of a 171 tube, we use the following formula:

\[ Z = \frac{V}{I} \]

Where:
- \( Z \) = Plate impedance (ohms)
- \( V \) = Change in plate voltage
- \( I \) = Change in plate current

**EXAMPLES**

1. **No. 1.** What is the plate impedance of a 171 tube with 180 volts on the plate and a negative grid bias of 40 volts?

   See curve 5 on Sheet No. 68. The X indicates that point on the curve corresponding to the conditions given in the example (i.e., 180 volts on the plate). The impedance is determined by first of all reading from the curve two different plate currents corresponding to two different plate potentials, with the same grid bias in each case. Any plate voltages may be taken provided we stay on the straight portion of the curve. Therefore, we might take plate voltages of 170 volts and 190 volts, corresponding to plate currents of 15.0 ma and 20.0 ma. The change in plate voltage is 190 - 170 = 20 volts, and the change in plate current is 26 - 15.8 = 10.2 ma. Therefore, the plate impedance of the 171 is equal to the change in plate voltage divided by the change in plate current: (10.2 ma, or 0.0102 amperes) which equals 190 ohms. This value corresponds very closely to that given for the UX-71 (2000 ohms) in Laboratory Sheet No. 58, in the January issue.

2. **No. 2.** What is the plate impedance of a 171 tube with 135 volts of battery and a grid bias of minus 230 volts?

   Refer to curve No. 3 and take any two plate voltages in the straight portion of the curve, say 130 and 150 volts. The corresponding plate currents are 13.8 ma and 20.3 ma. The plate-voltage change is 130 - 120 = 30 volts, and the plate-current change is 13.8 - 15.8 = 2.0 ma. Therefore, the plate impedance is 30 volts divided by 15.0 ma, or 0.016166 amperes, which gives 1816.8 ohms as the plate impedance.

Mathematically, it is evident that what we are determining is the reciprocal of the slope of the curve. The plate impedance is constant over the straight position of the curve. It is also apparent from an inspection of the curves that the output resistance or plate impedance is practically the same for all values of plate voltage, the slope of the curves being nearly the same.

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**No. 68**  
**RADIO BROADCAST Laboratory Information Sheet**

### Curves for the Type 171 Tube

![Curves for the Type 171 Tube](image)

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**No. 69**  
**RADIO BROADCAST Laboratory Information Sheet**

### Sources of Electrons

**THE HEATED FILAMENT**

The commonest source of electrons with which the home-constructor is familiar is the filament of an ordinary vacuum tube. Present theory regarding metals indicates that they are made up of atoms, which are, in turn, composed of electrons. These electrons are in violent motion and it might be expected that some of them would leave the metal, but there is an opposing force which holds them in position at ordinary temperatures. If the metal is made hot, however, the velocity of the electrons increases to a very great extent, and some of them do escape. The easiest way to heat the metal is to make it in the form of a wire and send an electric current through it. This creates an excellent source of electrons. It is unquestionable that, by far the most important way of obtaining electrons commercially, is through the heating of wires. This method is used to obtain a source of electrons in vacuum tubes.

The vacuum tube was not a very useful instrument at first until it was found that by placing a metal grid between the filament and plate, the number of electrons passing to the plate could be controlled. Some years after this first discovery, it was found that the vacuum tube would act as an amplifier of weak electric impulses, such as telephone currents. The three-element tube, as it is called, has opened up an entirely new field of research and is doubly one of the most important tools in the hands of science.

There are, however, other sources of electrons which are used to a considerable extent in scientific practice. It has been found that sometimes it will give off electrons if they are placed in a strong light. This is true of zinc, for example. Under ordinary light, zinc does not give off many electrons, but under the influence of light of very short wavelength, such as ultraviolet light, it will give off electrons quite rapidly. This effect is known as the photoelectric effect. Other metals, such as steel and tin, are very sensitive to light in the visible part of the spectrum. Potassium, for example, is used in some photocells where its function is to control electric currents in proportion to the amount of light that is permitted to fall on it. The photoelectric cell is one of the most important units used in a picture transmitting system. The effect produced in the cell is of interest to physicists because of the information it can give them regarding the nature of the electron.

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**Sockets-Adapters Connectoralds—Audio Amplification and Television**

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Factories at Canton and Westlake, Mass.

No. 70

RADIO BROADCAST LABORATORY INFORMATION SHEET

Soldering

ESSENTIALS FOR GOOD WORK

Fuel A receiver is to operate efficiently and quietly it is essential that all of the soldered joints be securely made. Soldering is an exceedingly important operation in wiring a receiver and poor soldering is a doubtful cause of frequent troubles.

The ordinary solder consists of a combination of lead and tin, the percentages generally being 50 per cent. lead and 50 per cent. tin. In order to make a good joint, the surfaces to be soldered should be entirely free from oxides. Soldering flux will prevent the formation of oxides while the heat is being applied. Those parts which are to be soldered should be scraped clean before the flux is applied and, under proper conditions, the solder will flow very easily around the joint when the parts have been heated sufficiently.

If the soldering is correctly done, the solder will appear bright after the joint is made, but a poor joint made with a cold iron will generally leave the joint of such a brittle crystalline structure. Some fluxes should be used very sparingly in making the joint, as they will contaminate the current and will also have a very detrimental effect on any insulation with which they come in contact. Rosin is a very excellent flux to use, although it is somewhat more difficult to work with than the ordinary soldering

paste. It is standard practice in most large electric companies to use rosin flux almost exclusively, since it has no no; heat on ision. When rosin is the flux it is important that a very hot iron be used or of the iron is not called a rosin iron, the solder will not be fusible, in which case there is a thin layer of rosin left on the joint, which makes the electrical conductivity of the joint very poor if it does not completely prevent the flow of current.

It is mentioned above, it is essential that the iron be sufficiently hot but a good job is to be done. A hot iron will also, in many cases, prevent other troubles. If soldering is attempted with an iron that is not hot enough, it is necessary to hold the iron on the joint a little longer, but the solder becomes sufficiently hot to melt and, during the process, much of the flux is driven off. With a hot iron, the least amount of heat is generally necessary, and the job is complete quickly. This is important when we are, as an example, soldering a lead to a lug on a transformer. In such a case it is essential that the job be done quickly so as to prevent heating the lug to such an extent that we lead from the winding which connects internally to the other end of the lug will not come unsoldered and thus cause the circuit to be broken.

No. 71

RADIO BROADCAST LABORATORY INFORMATION SHEET

Push-Pull Amplification

WHY IT IS USED

TRANSFORMERS are not the only source of trouble in line power-supply devices (B-battery eliminators).

Quite frequently it is found that a hum is audible in the output of the receiver when it is operated from a power supply. This hum need not necessarily indicate poor design, and may be due entirely to mechanical vibrations which can be eliminated by moving the device further from the receiver, or by placing the receiver on top of several layers of soft cloth.

Trouble in the power-supply unit may be the result of breakdown of one of the filter condensers, the breakdown of one of the resistances controlling the intermediate voltage taps in a defective rectifier, or to open connections. In testing the device, a voltmeter is essential. It should be correctly connected between the negative post and the various taps, and if one of the taps gives no reading, the trouble is probably due to a defect in the resistance unit supplying that tap. They are the most common cause of trouble and, therefore, good resistances, capable of carrying the current without excessive heating, must be used.

Defective resistances are a source of creating home-made "static." If reception is accompanied by considerable noises when using the power-supply device, the anterior should be disconnected and, if the noise persists, and the connections and joints should be carefully examined. Be sure that the A-battery terminals are not corroded. If possible, substitute for the power unit used dry B batteries, and if there is no noise, it is a good indication that the line power-supply device is causing the trouble. Defective resistances are the commonest cause of this noise and they should be carefully examined.

If no voltage readings can be obtained on any terminals, the rectifier tubes should be examined. Make sure that the filament has not burned out, or that the rectifier is of the incorrect type, but that it contains sufficient selenium. The filter condensers and, if possible, should be tested with a voltmeter and B battery to make sure they have not burned out. In this manner the current is separated into the rectifier, tube and the apparatus. In good condition it will be best to try a new receiver tube in the correct socket. Rectifiers in which a filament is used are constructed in the same manner, and in this case the fact that they light does not necessarily indicate that they are good. If the rectifier, tubes are counted unsuitable to supply connections (especially large currents) and will be extremely well made with very strong filaments if they are to last any great length of time.

The fact that we power our receiver from a line power-supply device does not mean that it is on the other side of the line. If everything is going to last forever. The rectifier device may wear out after considerable use, and the condensers, sometimes break down as they become old.

No. 72

RADIO BROADCAST LABORATORY INFORMATION SHEET

A. C. Operated Power-Supply Devices

TROUBLE SHOOTING

LESS COMMON TROUBLE is caused by the introduction of external currents or the lines into which the device is connected, and, if the noise persists, and the connections and joints should be carefully examined. Be sure that the A-battery terminals are not corroded. If possible,
No. 73

**RADIO BROADCAST Laboratory Information Sheet**

**An A. C. Operated Power Amplifier**

**CONNECTION TO AN ORDINARY RECEIVER**

Many standard a.c. operated power-supply devices available at present are capable of supplying sufficient voltage for the proper operation of a 171 type tube. When this tube is used in conjunction with such a device in an ordinary receiver, the filament is usually lighted from a storage battery and a dry cell used to bias the grid of the tube. A few slight changes, however, will make it possible to light the filament of the 171 from an a.c. source and to obtain the necessary grid bias by means of a resistance in the plate circuit of the tube.

The following parts will be required:

1. An ordinary bell transformer giving about 6 volts on the secondary.
2. 200-ohm potentiometer.
3. 500- to 1000-ohm variable resistance.
4. 25,000-ohm fixed resistance.
5. 2-mfd. bypass condenser.
6. 10-ohm rheostat.
7. Output choke coil.

A circuit arrangement such as is shown makes the one-stage power amplifier entirely independent of any local supply of energy, since all the necessary voltages are now being drawn from the a.c. power line. In the operation of the unit, the potentiometer, P, should be adjusted to that point at which the hum in the output circuit is at a minimum. Generally it will be found that the center point of the potentiometer will give minimum hum.

The variable resistance, R, controlling the grid bias, should not be lowered to a value less than 1000 ohms. It should be adjusted to that value (something above 1000 ohms) which gives the best quality of reproduction.

---

No. 74

**RADIO BROADCAST Laboratory Information Sheet**

**Resistance-Coupled Amplifiers**

**GRID LEAK-COUPLING COMBINATIONS**

Some information regarding resistance-coupled amplifiers is to be found in an article by Sylvan Harris published in the December, 1926, issue of the Proceedings of the Institute of Radio Engineers, and, incidentally, the data given in the proceeding confirm some calculations and measurements made by the Laboratory of Radio Broadcast about a year ago.

Then, a mathematical analysis is made of the resistance-coupled amplifier, it becomes evident that a very large coupling condenser need not necessarily be employed. It is the combination of the coupling condenser and the grid leak which determine the quality that can be obtained from such a combination. If the coupling condenser is made large, the grid leak resistance may be made small, and if the coupling condenser is small, the grid leak resistance can be increased a proportional amount, and the same frequency characteristic will be obtained in each case.

In the article in the Institute's organ, some curves were given showing the relationship between the value of the grid leak resistance and the size of the coupling condenser for a 202-A type tube. From these curves we can easily determine what value of coupling condenser must be used in conjunction with any particular grid leak, in order to obtain a certain definite frequency characteristic.

If a 100,000-ohm resistance is used in the plate circuit, the following combinations of grid leaks and coupling condensers may be used to obtain a practically flat characteristic curve down to 50 cycles.

**GRID LEAK**  COUPLING CONDENSER

| 0.2 megohm | 0.06 mfd. |
| 0.5 megohm | 0.025 mfd. |
| 1.0 megohm | 0.012 mfd. |
| 2.0 megohms | 0.005 mfd. |

The greatest trouble with resistance amplifiers is due to the blocking of the grids which sometimes takes place. It is unlikely, however, that this blocking will occur unless one of the tubes is being overloaded. This makes it essential that the proper C-battery bias be used on the grids of the various tubes. It is possible to calculate the required value of the grid bias if the characteristics of the circuit and the amplification constants of the tubes are known. These calculations indicate that for a 20-mu tube the C battery bias on the first high-mu tube should not be more than 1 volt, and that 4 volts is about right on the grid of the second high-mu tube. These values are high enough to handle a grid swing of 40 volts peak value on a 171 type power tube in the last stage.

---

No. 75

**RADIO BROADCAST Laboratory Information Sheet**

**Interference Finder**

**A PORTABLE RECEIVER**

On **LABORATORY** Sheet No. 76 is given a circuit diagram of a small portable receiver for use in locating sources of interference. In order to make up this receiver, the following apparatus is necessary:

1. Any standard loop, tapped at the center.
2. Variable condenser designed for operation with the above loop. Any value between 0.0025 and 0.0025 mfd. is satisfactory.
3. 0.01 mfd. grid leak.
4. Midget condenser, 0.001 mfd. max.
5. Audio-frequency transformers.
7. 0.01-ohm rheostat.
8. Radio-frequency choke coil which may consist of several turns on No. 32 or smaller wire wound on an ordinary spool.

To operate this receiver the following accessory equipment is necessary:

Three ordinary dry cells for the filament circuit; one small 4-volt battery for the plate circuits of all three tubes.

Three 199 tubes.

The receiver is of the ordinary regenerative type. The condenser, C, controls the tuning, while condenser Cc controls the amount of regeneration. When Cc is advanced near to its maximum position, the detector tube will oscillate so that stations may be picked up by a heterodyning whistle.

The loop should be mounted so that it can be turned in any direction. It will be found that the loop is very directional and that, therefore, in interference investigations, the interference will be picked up first when the loop is pointed toward the source. In this way the actual source of interference can often be located.

The receiver should be made extremely portable and, for this reason, it is preferable to enclose the batteries and loop, as well as the receiver, in a small carrying case that can be easily handled. The receiver should be equipped with a switch into which a separate loop may be plugged, or the loop may be wound inside the case itself. The filament rheostat controlling the tubes should not be advanced further than necessary to obtain satisfactory reception since excessive filament voltage on the 199 tube is very detrimental. It will be found that three ordinary dry cells used for filament lighting will last for many months.

Write for descriptive literature

**AMSCO PRODUCTS**

418 Broome St., New York City
No. 76  
RADIO BROADCAST Laboratory Information Sheet

Interference Finder

USE OF COILS AND CHOKE

When interference is experienced from motors, telephone rings, or other similar apparatus, it may frequently be eliminated by using some such circuit arrangement as is illustrated on this sheet. This circuit is called a filter, and can easily be connected to practically any piece of apparatus that is causing interference. If, for example, a motor is found to be causing the interference, such may be eliminated by connecting two chokes across the line terminals of the motor with the mid points grounded, as illustrated in the sketch. The values of the chokes should, in general, be more than 2 mfd., although smaller size chokes will sometimes give satisfactory results. In extreme cases of interference, where it is found that the chokes shunted across the line with their mid point grounded do not remedy the trouble, the inclusion of choke coils in series with the line is necessary. These choke coils must be fairly large and wound with wire large enough to carry the full current in the line. The shunting condensers and the choke coils, if they are used, should always be placed as close to the source of interference as possible. The source of interference is not always obvious, and, for that reason, it is advisable first to make some simple tests to make certain of the cause. In such an investigation the simple portable receiver described on the Laboratory Sheets Nos. 75 and 76 will be found very useful.

Before installing arc condensers, one should make certain that they have a rating sufficiently high to withstand the voltages under which they must operate. There will be little difficulty in obtaining satisfactory condensers for use on direct-current circuits since there are many on the market ranging at as high as 100 volts or more. Frequently these same condensers are not satisfactory for use on a.c. circuits, however, and consequently, if the device to be shunted is operated from a.c., make sure that the condensers used have a satisfactory a.c. rating.

No. 77  
RADIO BROADCAST Laboratory Information Sheet

Interference Elimination

USE OF CONDENSERS AND CHOKE

When interference is experienced from motors, telephone rings, or other similar apparatus, it may frequently be eliminated by using some such circuit arrangement as is illustrated on this sheet. This circuit is called a filter, and can easily be connected to practically any piece of apparatus that is causing interference. If, for example, a motor is found to be causing the interference, such may be eliminated by connecting two chokes across the line terminals of the motor with the mid points grounded, as illustrated in the sketch. The values of the chokes should, in general, be more than 2 mfd., although smaller size chokes will sometimes give satisfactory results. In extreme cases of interference, where it is found that the chokes shunted across the line with their mid point grounded do not remedy the trouble, the inclusion of choke coils in series with the line is necessary. These choke coils must be fairly large and wound with wire large enough to carry the full current in the line. The shunting condensers and the choke coils, if they are used, should always be placed as close to the source of interference as possible. The source of interference is not always obvious, and, for that reason, it is advisable first to make some simple tests to make certain of the cause. In such an investigation the simple portable receiver described on the Laboratory Sheets Nos. 75 and 76 will be found very useful.

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No. 78  
RADIO BROADCAST Laboratory Information Sheet

The Volt, Ampere, and Ohm

DEFINITIONS

WE ARE giving below an explanation and meaning of the common terms, the volt, the ampere, and the ohm. Hydric analogies will be used in explaining the first two of these terms.

AMPERE: A current of water in a pipe is measured by the amount of water that flows through the pipe in a second, such as 1 gallon per second, or 10 gallons per second, etc. Electricity is measured by the amount of current that flows along a wire in one second. This quantity is known as the coulomb, and if this term is used we would express the current as 1 coulomb per second or 10 coulombs per second, etc. In electricity, however, we have a special name for the rate of flow of 1 coulomb per second which we call 1 ampere. Thus, 8 amperes is the same as 8 coulombs per second. Ampere, then, is a term defining the quantity of current that is flowing per unit of time.

VOLT: The number of gallons per second of water flowing in a pipe, or the number of amperes flowing in a wire, depends upon the pressure under which it flows. The electrical unit of pressure is the volt.

A volt means the same thing as speaking of a current of electricity that a pound pressure means in speaking of a current of water. It follows then that the greater the pressure (voltage) at the supply, the greater will be the flow of current.

Ohm: There is no hydraulic unit which corresponds to the ohm, which is a measure of the resistance of a wire to the flow of current. A wire is said to have a 1 ohm of resistance when a pressure of 1 volt will cause a current of 1 ampere to flow through it. If the resistance were doubled, the current would be halved, etc.

According to the definition given on this Sheet, then, we see that amperes represent the amount of current, volts the pressure causing this current to flow, and ohms the resistance opposing the flow of current. These three units have a definite relation to each other. This relationship, named after the scientist who discovered it, is known as Ohm's Law, which states that the number of amperes flowing in a circuit is equal to the voltage of the circuit divided by its resistance. An explanation of Ohm's Law is given on Laboratory Sheet No. 81.
**Regulating Voltage on B Power-Supply Device**

**USE OF RESISTOR**

Many commercial a.c. operated power-supply devices are equipped with taps for supplying different voltages for use in conjunction with the detector, amplifier, etc. The voltage obtained from any tap on such a device is not constant but varies with the amount of current that is drawn from it. If an unusually heavy load is drawn from any one of the taps, it will generally be found that the voltage is somewhat less than the specified amount. In such a case, it is possible to increase the voltage on the particular tap which is low by connecting an external resistance between the tap whose voltage is low and the maximum voltage tap on the device. The proper connections for this resistance are indicated in the diagram, and, by the proper variation of this resistance unit, it will be found possible to obtain any value of voltage that might be required. This method of increasing the voltage on any tap is very simple, since it does not require that the power-supply device be opened and the internal resistances varied.

It should be noted that the resistance does not connect between the two adjacent taps but that it is connected between the 45-volt tap and 135-volt tap which, in this particular case, is supposed to be the maximum voltage tap on the device. This method of increasing the voltage on any tap was suggested in the December issue of the General Radio Experimenter.

The resistance should be variable between 5000 and 50,000 ohms, and must be of a type satisfactory for use in power-supply devices.

---

**Characteristics of Tubes**

**MEASURING THE AMPLIFICATION CONSTANT**

Laboratory Sheet No. 68 (February, 1927) gave some characteristic curves of the 171 type tube, and Sheet No. 67 explained how the plate impedance of the tube might be calculated using these curves. The present sheet will explain how the amplification constant is calculated.

The amplification constant is the measure of the effect of the grid voltage on the plate voltage. Stated as a formula, the amplification constant equals:

\[ \text{Amplification Constant} = \frac{V_p}{V_g} \]

*Change in Plate Voltage* = *Corresponding Change in Grid Voltage*

We are giving two examples below which will make simple the calculation of the amplification constant of any tube, provided its characteristic curves are available.

**Example 1:** Calculate the amplification constant of the 171 type tube, using the curves given on Laboratory Sheet No. 68. In this example we shall use curve No. 3. Locate some point on curve No. 2. In this example we are taking the point corresponding to 100 volts, then find the point on the same curve at which the plate current will vary by a corresponding amount.

Finding the horizontal line corresponding to this plate current until we come to curve No. 3, we find that the corresponding plate voltage on this curve is 129. We then have two voltages: 100 and 129, corresponding to two different grid biases, 16.5 and 27. Both of these values are for the same value of plate current. These values can be substituted in the above formula as follows:

\[ 129 - 100 = 29 \]
\[ 27 - 16.5 = 10.5 \]

Solving this formula, we get a value of 2.67, which is the amplification constant of this particular 171 type.

**Example 2:** Find some point on curve No. 4, taking that point corresponding to 180 volts as an example. In this case a plate current of 23.3 milliamperes is obtained. Following across to the corresponding plate current on curve No. 5 we find that the plate voltage is 179. The difference in plate voltage between these two points is 19 and the difference in grid bias is 46.5 minus 35, or 11.5. Dividing these two, we obtain a value of 2.54, the amplification constant of the 171 type.

It should be noted that this latter result is somewhat different from that given in the preceding example due to the fact that the tube was considered to be operating under different voltages.

The amplification constant varies slightly for different plate voltages, but the variation over the operating range of plate voltage and grid voltages is not usually more than 10 per cent.

---

**Ohm's Law**

Some examples:

1. If a tube's filament has a resistance of 20 ohms and five volts are applied to it, a current of 1 ampere will flow. If the filament resistance is one half this figure (10 ohms), then the current, for the same applied voltage, will be twice as large, or 2 amperes.

To determine these currents, we have used a fundamental relationship regarding the current, voltage, and resistance of any circuit, known as Ohm's Law, which states that the current in a circuit is always directly proportional to the voltage and inversely proportional to the resistance. Therefore, in the case of a filament, halving the resistance doubles the current, and doubling the resistance reduces the current to half. Inversely, doubling the voltage doubles the current, and halving it gives half the current.

These facts can be expressed in the form of a simple algebraic equation as follows:

\[ I = \frac{E}{R} \]

in which \( I \) is the current in amperes, \( E \) the voltage, and \( R \) the resistance in ohms.

The equation shows that the current is equal to the voltage divided by the resistance. It can be rearranged so as to make it easy to solve for voltage or resistance as well as current.

To determine an unknown voltage, use the equation in the following form:

\[ E = I \cdot R \]

where \( E \) is the voltage in volts, \( I \) is the current in amperes, and \( R \) is the resistance in ohms.

---

**SUCCESS with AC TUBES**

is based upon the electrical balance of the filament circuit. Perfect balance eliminates the "hum"... The importance of attaining perfect filament circuit balance is stressed in all vacuum tube literature.

Due to individual tube variation, non-uniform length of filament wiring and the use of rheostats to control filament voltage, centre tapped fixed resistances do not afford utmost satisfaction... AMSCO "Tom Thumb" low resistance potentiometers are ideal for obtaining filament circuit balance in A C tube circuits...

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No. 82

Oscillation Control

A COMPARISON OF TWO COMMON METHODS

IT IS the purpose of this Laboratory Sheet to compare two methods commonly used to control oscillations in the radio-frequency amplifiers of receivers.

The first method to be discussed is that using a potentiometer to vary the bias on the grid of the tube. This method is illustrated in Fig. 1, in which \( P \) is the potentiometer, and \( C \) is a bypass condenser functioning to bypass the radio-frequency energy directly to the negative filament.

When the potentiometer arm is connected to the negative side, the amplifier operates most efficiently and the result is that oscillations are prevented. To prevent the oscillations from occurring, the potentiometer arm is moved toward the positive side and this makes the grid positive, lowers the efficiency of the circuit, and thereby prevents oscillations.

The second method is indicated diagrammatically in Fig. 2, in which case the oscillation control is a variable resistance, \( R \), in the plate circuit of the tube. In this case a bypass condenser is again used to bypass the radio-frequency energy to the negative filament. This oscillation control functions by lowering the value of voltage impressed on the plate of the tube. In this manner the plate impedance of the tube is increased and oscillations prevented.

The second method is to be preferred over the first since it has several distinct advantages. In the first place the plate current consumption, using the second method, is quite low, whereas, in the first method, in order to prevent oscillations it is necessary to make the grid positive, which causes the plate current to increase to comparatively large values. The second method does not lower the selectivity of the receiver. This is not true of the first method because, when the grid becomes positive, a load is placed on the tuned circuit, and the resistance of the circuit is thereby increased. The result is that it tunes broadly, or, in other words, the selectivity of the receiver is lowered.

In practice, the resistance used in Fig. 2 generally has a maximum value of about 500,000 ohms.

No. 83

Tube Characteristics

MUTUAL CONDUCTANCE

ON LABORATORY Sheet No. 84 is given a graph of plate current vs. voltage across the grid of a 120 tube, while on this Laboratory Sheet we will calculate the mutual conductance of the 120 tube with the aid of these curves.

The mutual conductance is a measure of the effect of an applied voltage on the plate current of a constant grid voltage. Stated as a formula, the mutual conductance equals:

\[
\text{CHANGE IN PLATE CURRENT (AMPERES)} \times \text{CORRESPONDING CHANGE IN GRID VOLTAGE (VOLTS)}
\]

We are giving below some examples that will make simple the calculation of the mutual conductance of any tube provided its characteristic curves are available.

Example 1

Calculate the mutual conductance of a 5 BB4 type tube using the curves given on Laboratory Sheet No. 84. At any point on curve No. 3, as for example, that indicated by the cross. This point corresponds to a plate current of 5.4 milliamperes, a plate voltage of 120, and a grid bias (Eg) of minus 25 volts. Follow along on the 120-volt line to curve No. 2, and we find that the plate current is 5.4 milliamperes for a grid bias of minus 225 volts. We now have two values of grid voltage and two values of plate current for the same plate voltage. Changing the milliamperes to amperes, and substituting in the formula, we have:

\[
\begin{align*}
\frac{(0.0054 - 0.0025)}{(25 - 22.5)} & = 0.0016 \\
& = 0.0004 \text{ mmhos} = 400 \text{ micromhos}
\end{align*}
\]

Example 2

Calculate the mutual conductance of the 120 tube for a lower value of plate voltage, say 36. To do this we will locate the point on curve No. 1, corresponding to 60 volts on the plate and this point, indicated by a cross, gives a plate current of 3.2 milliamperes for a grid bias of minus 22 volts. This same voltage on curve No. 3 gives a plate current of 4.7 milliamperes for a grid bias of minus 195 volts. Substituting these values in the formula:

\[
\begin{align*}
\frac{(0.0037 - 0.0003)}{(22.5 - 15)} & = 0.0016 \\
& = 0.0003 \text{ mmhos} = 300 \text{ micromhos}
\end{align*}
\]

It is evident from these two values of mutual conductance that the 120 give very low values when low plate voltages are used. Practically the only voltages which can be used on the 120 tube with satisfactory results are 135 volts on the plate and minus 225 on the grid.

Researchers interested in calculating the other constants of a tube are referred to Laboratory Sheets No. 67, February, 1927, and No. 80, March, 1927.

No. 84

The Type 120 Tube Characteristic Curve

<table>
<thead>
<tr>
<th>Plate Voltage</th>
<th>Plate Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0054 A</td>
</tr>
<tr>
<td>36</td>
<td>3.20 A</td>
</tr>
<tr>
<td>60</td>
<td>4.70 A</td>
</tr>
<tr>
<td>120</td>
<td>5.40 A</td>
</tr>
</tbody>
</table>

RADIO BROADCAST's DATA SHEETS
C Voltages

FACTORS DETERMINING VALUE

The C-battery voltage that can be placed on any tube indicates the amplitude of the signal voltage that the tube can handle without seriously overloading. For example, the 171 tube with 180 volts on the plate requires a 40.5-volt C battery. Any signal can be impressed on this tube, therefore, whose peak value does not exceed 40.5 volts.

Ordinarily we do not talk of the maximum values of alternating current voltages but speak instead of the effective values, which are equal to 0.707 times the maximum or, so called, peak value. In other words, a voltage with a peak value of 40.5 has an effective value of 28.6. If signals greater than this are impressed on the tube, the grid voltage will swing at times it becomes positive and it will then draw a small amount of grid current, which it does not do when negative. Even very small grid currents flowing through the secondary of a transformer have a very serious effect on their operation. Consequently, in amplifier work it is an axiom that the grid voltage must never be permitted to swing an amount exceeding the value of the C battery. The handling capacity of a tube can be increased by increasing the grid voltage up to a certain point. Beyond this point, an examination of the tube characteristic would indicate that the signals will cause the grid to operate on the lower curved portion of its characteristic. The manufacturer's C-battery ratings are generally the highest that can be used and still operate the tube on the straight portion of the characteristic. As an example, when the 201-A tube is used in an amplifier with 90 volts on the plate it is recommended that the C-battery voltage be 41, and this can be taken as the value of C battery which will permit the tube to handle the greatest amount of undistorted power.

The C-battery voltage used on any tube is a definite value of signal voltage on the grid of the preceding tube in order to place the maximum allowable signal voltage on the grid of the last tube. See Laboratory Sheet No. 88. Consequently, the voltage on the grid of the tube preceding the last tube need only be sufficiently great to prevent its grid from going positive on the maximum signal necessary to give maximum voltage on the grid of the second tube.

A Double Impedance-Coupled Amplifier

A SCHEMATIC diagram of a double-impedance coupled amplifier is shown on Laboratory Sheet No. 87. The material required to build such an amplifier is given on page 30. Interconnections are shown on Sheet No. 89. The parts and instructions for the construction of the amplifier itself are given on the following page. However, the best results will be obtained if the inductance is about 100 henrys, however, the exact value of inductance is not very critical, so long as it is not less than 60 henrys. The choke coil in the plate circuit of the preceding tube is a fixed choke capable of carrying the plate current drawn by this tube. For a 171 tube with 180 volts, the plate current will be as high as 20 milliamperes. Lx—Grid impedances. These should have a value of inductance of about 100 henrys. Three of these coils are required.

C—Coupling condensers, having a capacity of 0.1 mfd. These condensers must be well constructed since, if poor units are used, a certain amount of leakage occurs across the condensers. Well-constructed paper condensers are quite satisfactory.

N—Grid output condenser.

R—Fixed filament control resistance of a type depending upon the kind of tubes used. It must be capable of passing the total filament current of the three amplifier tubes.

S—Filament switch.

T1—Two high-mu tubes. Two 201-A's may be used, but the application will not be as good.

Ta—Power tube of either the 112 or 117 type. The C-battery voltage on the last stage depends upon the type of tube and the plate voltage that is used.

It will be found that an amplifier of this kind will give excellent quality. It can be used in conjunction with any receiver. It may be built in such a way as to connect the input of the amplifier circuit to the detector circuit of the receiver. The terminal marked plate on the input connector is connected to the plate of the detector tube and the R plus grid terminal connects to the plus 45-volt battery terminal. In those receivers using a tickler, the B detector terminal would connect to one end of the tickler winding instead of directly to the plate of the detector tube.

People frequently ask if the primaries or secondaries of old-style transformers might not be used as impedances in an amplifier of the type under discussion. This is not feasible, for the characteristics which cause old-style transformers to give poor quality, also make them unsuitable for use as impedances. High inductance windings and well-designed cores are not to be found in old transformers, and it is desirable that an impedance unit have both of these.

Dual-impedance Coupled Amplifier

Plates

No. 85

C. R. B. Laboratory Information Sheet

No. 86

C. R. B. Laboratory Information Sheet

No. 87

C. R. B. Laboratory Information Sheet

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424-438 West 33rd Street, New York

No. 88

audio amplifying system

No. 1. Transformer Amplifiers

The conventional transformer-coupled amplifiers consist of two stages: one for amplification of such a system is generally around 300, and this is sufficient enough to give loud speaker reproduction with a moderate volume. This signal available to the output of the detector. The transformer-coupled system has been used, and it has been found that only two stages are required and can, therefore, be made quite compact.

The plate current consumption of such an amplifier is fairly low and only moderate high voltages are necessary on the secondary. This quality of the resulting signal obtained depends primarily upon the transformers used and for this reason a certain amount of care is necessary in choosing the transformers that are to be incorporated in such an amplifier.

The transformer feeding out of the detector stage should have a primary impedance that is somewhat higher than is necessary for that transformer used in the second stage. The higher impedance is necessary in the transformer feeding out of the detector tube due to the fact that the detector place circuit generally makes a somewhat higher impedance than the plate circuit of a tube used as an amplifier.

If two transformers of different ratios are to be used, the rule is almost invariably to place the lower ratio transformer in the first stage and high-ratio transformer in the second stage. For commercial reasons, most manufacturers use a fixed number of turns on the secondaries of their transformers irrespective of the ratio required. The different values are then obtained by winding on the necessary number of primary turns. The ratio of the transformers will be of course varying proportionally with the ratio. Thus, the lower the ratio the greater the number of primary turns and likewise, the greater the primary impedance.

Proper C battery on the amplifier tubes is absolutely essential, good grid bias is to be obtained. The C battery voltage on the first stage should not be higher than is necessary to prevent overdriving. Placing an unnecessarily high bias on the first tube increases the plate dissipation in the tube, and it is essential that the plate impedance be kept low.

If 171 tube is used in the last stage with a 40 volt C bias, we can impress signals on the grid of this tube which have a peak value up to 40 volts. If the transformer has a ratio of 4.1, the peak value of the voltage in the primary will be 10 volts. If a 201-A tube is used in the input stage, we can obtain the value of peak voltage on its grid by dividing the voltage in the plate circuit, 10 by the amplification constant of the tube, 8, which gives 11 volts. It follows then, that a C battery bias of 4 volts on the first tube will be sufficient to prevent overloading.

No. 89

Short-Wave Coils

SOME DATA ON THEIR RESISTANCE

There are not many excellent coils on the market for use in short-wave receivers. They are generally of the "plug-in" type so that different coils are used to obtain the various ranges needed.

These coils should have as low a radio-frequency resistance as possible, consistent with a construction sufficiently rugged to prevent their being damaged if they are handled roughly. It would be preferable if the coils could be wound so that some form of question arises whether or not a form can be used without increasing the resistance of the coil to a considerable extent.

The General Radio Company has conducted some experiments along this line to determine just how much the form used affects the coil's resistance and also to determine what size wire is best to use. Tests were made using a standard bakelite form having a diameter of 21/8". The curve given on this page indicates how the radio-frequency resistance of the coil varies with the size of the wire used. Evidently, from the curve, the wire size is not as critical as was believed, but test results are obtained with a wire of about No. 120, .014 gauge.

It was found that the use of good binders to hold the turns in place has no appreciable effect upon the resistance. A coil was wound in such a manner that a form could be slipped in and out of it without disturbing the wire. Measurements on the coil with and without the form indicated that the difference in efficiency was negligible.

Tests were also made with regard to shielding and it was found that the shielding could be placed there very near the coil and have no appreciable effect. The result of the tests may be summed up as follows:

When designing a coil for use on the 40-meter band.

No. 90

Loop Antennas

SOME OF THEIR ADVANTAGES

The operation of a loop is usually explained by saying that the current flowing in the primary sets up an alternating magnetic field in which a current is set up in the secondary. This also is the simplest way to explain the operation of a loop antenna, the only difference being that the alternating magnetic field that causes the current to flow in the loop is in the form of radio waves.

The number of volts induced in a loop by the passage of radio waves is

$$\mathcal{E} = \frac{V}{n} H \times 10^8$$

where $\mathcal{E}$ is the magnitude of the wave, $\mathcal{F}$ the frequency, $n$ the number of turns in the loop, and $A$ the size of the loop. This formula is not only correct when the plane of the loop is vertical but is also true in the direction of the magnetic field. That is, the loop must be pointing toward the transmitting station. If rotated about a vertical axis only a quarter of a turn, no voltage will be induced low and only a very weak signal is passed.

This feature is the most important advantage of a loop, for in two stations using exactly the same wave-lengths and having a large number of loops separated (provided they do not lie in the same or exactly opposite directions) by simply turning the loop at right angles to the interfering station, loops are coming into greater use as transmitting stations become more powerful and they will probably ultimately be used almost exclusively on account of the small space required, ease of installation, portability, lack of necessity to safeguard against lightning, and the improvement of the ratio of signal to interfering noise, due to their directional properties.

If a loop is compared in size to an antenna of the ordinary type it would appear that the signal intercepted by the loop would be exceedingly small. The fact is that a loop, properly tuned with a condenser having low insulation losses, will pick up much better than might be expected from a comparison of its size with that of an ordinary antenna. This is due to the fact that the loop has a very much lower resistance than an ordinary antenna.

The loop type antenna has been used most frequently in conjunction with variable condenser for tuning. During the last year, however, several receivers of the push-pull type have been put on the market designed for use with a loop. These receivers are generally completely shielded and the only possible interaction between the loop and the coils in the receiver.

Radio Broadcast Laboratory Information Sheet

Set of Three Coils, with Plug-In Base
$10.00
Plug-In Coils, each
$2.50
$1.00
No. 91  RADIO BROADCAST Laboratory Information Sheet

A Simple Tube Tester

HOW TO GET CHARACTERISTICS OF TUBES

Contrary to the opinion of many experimenters, a set-up of instruments to measure the characteristics of vacuum tubes is not excessively costly nor is it complicated. The diagram of connections of a tester is shown on Laboratory Sheet No. 92; this Laboratory Sheet will explain how to measure tube characteristics using this tester. The procedure can be explained most easily by taking an actual example.

Suppose we desire to measure the characteristics of a 201-A tube. We would first place the tube in the socket and then, with switch No. 2 in position B and switch No. 3 in position A, the rheostat would be turned until the d-c voltage, as read on the voltmeter, is correct. In this case the correct voltage would be 25 volts. Then, with switch No. 3 in position B and the plate voltage is adjusted to 30 volts, the grid bias is next adjusted to 4.5 volts by throwing switches Nos. 1 and 2 to the A positions and adjusting the potentiometer P. The milliammeter will now read about 0.002 amperes (2 m A). Note down the plate voltage, the grid voltage, and the resulting plate current.

Now adjust the potentiometer until the grid bias is, say 3.5, and read the plate current. It should read about 0.003 amperes (3 mA). Leaving the grid bias at 3.5, next adjust the switches to read the plate voltage. Reduce the plate voltage so as to make the milliammeter read exactly the same as before (2 mA). The new reading of plate voltage may be 82. We now have all the necessary data to calculate the characteristics of the tube.

Under the effect of the two plate voltages, 90.85, or 8, divided by the difference of the two grid voltages, 4.5 and 0, the amplification constant is therefore 8. The plate impedance is equal to the difference of the plate voltage divided by the difference in the plate currents, or 8 divided by 0.001. The quotient is 8000, which is the plate impedance. The mutual conductance is the plate current difference divided by the grid voltage difference, or 0.001 divided by 1 = 0.001 microhms in the milliammeter.

In measuring tube factors with this apparatus, care must be taken that the actual changes in voltages and the corresponding current changes are small. If the plate-current meter, and the grid-voltage meter, can be read with sufficient accuracy, very small changes should be made—say a plate voltage change of 5 volts. This, however, would make it necessary to read grid bias changes of less than a volt. The investigator, then, is between two fires in his endeavor to measure his tubes accurately. If he takes plate current readings resulting from large voltage changes, he gets a factor which represents working the tube over a large part of its characteristic curve. On the other hand, if he uses small voltage changes, the accuracy depends upon the accuracy of his meters and his ability to read them.

No. 92  RADIO BROADCAST Laboratory Information Sheet

Circuit Diagram of Tube Tester

No. 93  RADIO BROADCAST Laboratory Information Sheet

Audio Amplifying Systems

DUAL-IMPEDE MA COUPLED AMPLIFIERS

On this Sheet we give some facts regarding dual-impedance coupled amplifiers. A circuit diagram of such an amplifier will be found on Laboratory Sheet No. 87 (April, 1927).

Double-impedance amplifiers are capable of giving excellent results if care is taken in the selection of the apparatus and the layout of the parts. The plate impedances should have an impedance around 100 henries, if the inductance is much less, the output will be lost. Well-made 0.1-mfd. blocking condensers are essential to prevent leakages.

The amplification of each stage is generally equal to the product of the amplification constant of the tube. If we lose one tenth on each stage, the total amplification in three stages will be equal to 0.9 x 0.9 x 0.9 = 0.73 times the product of the amplification constants of the three tubes concerned. Suppose two 201-A's, each with an amplification of eight, and one 1271 with an amplification of three, are used. Then the total amplification will be equal to 0.8 x 8 x 3 = 19.2. From this it is evident that the audio transformer must have the ability to overcome the load of an impedance amplifier or two in order to get useful performance.

As assumed above, the amplification obtained at low frequencies depends upon the product of the impedances in the plate and grid circuits. There has been a recent development in this design feature which has the advantage of increasing the amplification of the impedance amplifier in the plate and grid circuit. The problem is to determine the impedance of the plate and grid circuit is to determine the impedance of the plate and grid circuit and the coupling condenser, that the entire combination is resonant at about 30 cycles, with the result that the amplification of these low frequencies is unusually good.

A New Note
In Audio Amplification

Supreme in musical performance, the new Thordarson R-300 Audio Transformer brings a greater realism to radio reproduction. Introducing a new core material, "DX-Metal" (a product of the Thordarson Laboratory), the amplification range has been extended still further into the lower register, so that even the deepest tones now may be reproduced with amazing fidelity.

The amplification curve of this transformer is practically a straight line from 30 cycles to 8,000 cycles. A high frequency cut-off is provided at 8,000 cycles to confine the amplification to useful frequencies only, and to eliminate undesirable scratch that may reach the audio transformer.

When you hear the R-100 you will appreciate the popularity of Thordarson transformers among the leading receiving set manufacturers. The R-100 retails for $8.00.

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STANDARD AUDIO TRANSFORMERS

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THORDARSON Z-COUPLER

The Thordarson Z-Coupler is a special audio coupling medium designed for use with screen grid tubes in the audio amplifier. May be used with either screen grid connection or space charged connection. Provides amplification equivalent of from two to three stages of ordinary coupling. This instrument has a wide tonal range providing realistic reproduction. Z-Coupler, $12.00.

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"Midgetí
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No. 94
Radio Broadcast Laboratory Information Sheet
The Principle of Reflexing
When a tube capable of amplifying a fairly strong signal is used to amplify a very weak one, it is evident that its power-amplifying ability is not being made use of to the fullest possible extent. "Reflexing" is a system for getting more out of a tube by making it amplify two things—the incoming signal, which is a radio-frequency current, and the detected signal, which is an audio-frequency current. The accompanying diagram indicates a simple receiver using one stage of reflected amplification.

In this receiver, the radio-frequency current enters the receiver via the antenna and is impressed on the tube by the tuned circuit, A. It then passes through the tube and into the tuned transformer, B, the output of which is impressed on a crystal detector. The direct currents resulting from the detecting action of the crystal pass through the audio-frequency transformer, T. The voltage induced in the secondary of this transformer is impressed on the grid of the tube and is amplified. A pair of phones is used in the plate circuit of the tube for receiving the signal.

So long as the variations of potential due to these two different signals do not cause the tube to overload, neither interferes with the other. Some circuits use a reflex principle consisting of several stages of radio-frequency amplification and several stages of audio-frequency amplification. In such sets it is advantageous to the system due to David Grimes and known as the Inverse Duplex system. In this system, the tube handling the smallest amount of radio-frequency energy is made to handle the largest amount of audio-frequency energy and, vice versa, the tube handling the greatest amount of radio energy handles the smallest amount of audio energy. In this way the point of overloading is not reached until both tubes have been forced fairly to obtain high efficiency from such a receiver.

No. 95
Radio Broadcast Laboratory Information Sheet
Storage Batteries
Necessary Care
The storage battery has been developed to a remarkable degree of perfection so that it will function over a long period of time with only a small amount of care. Much attention is given to it, but only an occasional checkup is required. The state of charge of the battery can be determined by a hydrometer reading, which gives a fairly accurate indication of the state of charge of the battery, with its reading, of course, being influenced by the length of time that has elapsed since the time the battery was fully charged.

Care should be taken in charging the battery to make certain that its positive terminal is connected to the positive terminal of the source being used for charging purposes. If the battery is charged in the opposite direction, the plates will be reversed in chemical character, and if the charging is continued for any great length of time, the battery will be destroyed. If a battery has only been charged in the wrong direction for a short length of time, it can generally be brought back to normal by charging it in the right direction for a very long time at a low charging rate.

No. 96
Radio Broadcast Laboratory Information Sheet
Analysis of Voice Frequencies
Relative Importance of Low and High Frequencies
Many investigations have been made to determine the relative importance of the various frequencies that are found in the human voice. For those who are interested in a high-quality audio amplifying system, the results of these tests are of interest. The tests were made by the Western Electric Company using such an amplifying system to determine the relative importance of different frequencies in the voice frequency range, and the results of these tests are shown in the curves on this page. These curves were obtained by inserting in the circuit low-pass (L.P.) filters, which will only pass low frequencies, and high-pass (H.P.) filters, which pass only high frequencies. The filter curves are shown in the diagram on the opposite page. The curve marked "Articulation H.P." shows that the articulation was reduced below 75 cent per cycle, and the articulation is only reduced 2 cent per cycle. Eliminating all frequencies above 400 cycles leaves remaining 60 cent of the total energy but the articulation is reduced only about 5 per cent.

The curves on the sheet were traced from an exact copy of a book by K. H. Johnson entitled Transmission Circuits for Telephone Communication.
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Master A. C. Model

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1 Hammarlund No. Hi Q-29 Coil Set.
2 Hammarlund No. SDW Knob-Control Drum Dials (Walnut).

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Benjamin Cle-Ra-Tone Sockets, No. 9040.
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1 Sangamo .001 mfd. Fixed Mica Condenser.
1 Carter No. 11-S "Hi-Pot" Potentiometer with switch, 100,000 ohms.

Hammarlund Electric Mfg. Co.
2 Thorodson No. R-300 Audio Transformers.
4 Parvort 5 mfd. Series 200 By-Pass Condensers

Acme Wire Co.
1 Durham Metallized Resistor, 14 megohms.
1 York No. 560 Cable Connector and Cable.
1 pr. Yasky No. 522 Insulated Phone Tip Jacks.
2 Yasky Mfg. Co.
2 Amperite No. 1-A.
1 Amperite No. 112.
2 Raffoil Co.
2 Eby Engraved Binding Posts.

1 "Hi-Q 29" Master Foundation Unit (containing drilled and engraved Westminster Micarta panel, three complete aluminum shields, drilled steel chassis, shafts, binding post strips, Phenolstock clips, fixed resistance units, resistor mounts, brackets, clips, wire, screws, nuts, washers, and all special hardware required to complete receiver).

Hammarlund Mfg. Co., Inc.
Radio Headquarters

Official Distributors for Leading Radio Products

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"Supreme" Service Instruments
Make More Money for Radio Service Men

YOU get more than a simple radio testing machine when you buy a Supreme Service Instrument. You get a laboratory-made accurate instrument that will save hours of time—insure a 100% correct diagnosis of any radio trouble—point the way to the quickest and best repair—and make money for you every day you work.

You guess no longer. When you analyze radio troubles with the Supreme you KNOW what the trouble is. Because you do KNOW, your customers have more confidence in you—you get better prices for service—you build up more business.

Makes Any Test on Any Set

When you go out on a service call you may find anything from a home-made "mongrel" set to a fine new A.C. set. They are all alike to the Supreme. You can test tubes for current-pass and oscillation—make all continuity tests—test condensers, batteries, loudspeakers, eliminators, audio-transformers, trickle-chargers, power tubes, or any other radio instrument. Make any test in any set and KNOW what is wrong right away.

Rejuvenates Tubes

In servicing a set you can make a good profit and win a permanent customer by rejuvenating or reactivating the filament tubes. Supreme Instruments will rejuvenate up to 12 tubes in the set at one time—in 10 minutes.

A Complete Portable
Radio Testing Laboratory

A fully equipped laboratory in a handsome brass-trimmed leatherette carrying case. Has all service tools and supplies necessary to step out on the job. Worthy of the finest radio engineer. Makes any test on a radio—and makes it accurately. FULLY GUARANTEED. Has—

A complete built-in power plant from A-C line.
Various fixed condensers from .05 to a 0.04.
A 30-ohm rheostat. A 500,000-ohm.
An 0-10,000-600 WESTON voltmeter. 1,000 ohms per volt.
An 0-125 mills 2½ amps WESTON ammeter.
An 0-5-15-150 WESTON A-C meter.
Selector type push button testing for selecting any scale on any reading.
Also Pin-jacks give access to all apparatus.

Supreme No. 99-A
A Practical Set Tester

The 99A is equal to the 400A in accuracy and quality but it does not have the laboratory equipment. Tests sets, rejuvenates tubes, broadcasts sound waves from A.C. etc. A practical service man's instrument. Very easily handled, even by service men who have not had extensive technical training. Equipped with a 0-10,000-600 WESTON voltmeter. 1,000 ohms per volt; WESTON 0-125-2½ amps milliammeter; 0-5-15-150 WESTON A-C meter, etc. Selector type push button testing for selecting any scale reading. Oscillator and power plant. In handy durable case: brass-bound leatherette. FULLY GUARANTEED.

No. 400 A

A Real Broadcast Station

Each Supreme Instrument is a miniature broadcast station. You can use it 24 hours a day to test sets when there is no other carrier wave on the air. Plugged into an A.C. socket it broadcasts a high-frequency wave (modulated) and enables you to test radio sets at any time.

Demonstrations Satisfy Customers and Make Sales

The Supreme Instrument, plugged into the set to be tested, actually becomes a part of the set. With it you can demonstrate the effect of new equipment—how the customer can improve his set. Your demonstration satisfies him that you know what you are talking about and makes sales of new tubes—new condensers—other new parts.

LIBERAL TIME PAYMENTS

Let your Supreme Instrument pay for itself in time-saving and actual added profits. You can pay $35 cash and 12 monthly payments of $1.00 each for the 400A; $28.90 cash and eight monthly payments of $1.50 each for the 99A. If you prefer to pay all cash the prices are $124.65 for 400A; $97.65 for 99A.

Examine Either Set Free

Make settlement with your express agent either on time payment plan or all cash as you prefer. Try set out thoroughly for six days. If you are not entirely satisfied return set within the six-day period, prepaid return charges, and your express agent will return the settlement you have deposited with him.

SUPREME INSTRUMENTS CORPORATION
GREENWOOD, MISS.

[Supreme Instruments Logo]
Methods of Generating High-Frequency Energy

THE ARC

Before the invention of the three-electrode tube, and its subsequent use as a source of large amounts of high-frequency energy, the arc was a common type of continuous-wave generator. In the drawing on this sheet is given the circuit diagram of a simple arc. The ordinary arc light used for street lighting might be used, but much more efficient operation is obtained from an especially designed arc, which is exactly that theory of the arc as given below.

The diagram indicates the simplest arrangement of the apparatus. "G" is a direct current generator, "r" is a resistance to control the current, L1 and L2 are two coils to keep the i. f. energy out of the generator and to keep the current practically constant. "K" is the arc, and "L" and "R" are respectively, the capacity, inductance, and resistance of the oscillating circuit.

The arc, which consists of two electrodes, is different from ordinary electrical conductors in one important respect, which is that its resistance is not a constant quantity but a variable one, depending on the current flowing through it. At high current values the resistance is low and at low current resistance is high. Consequently, an increase in current will produce a decrease in resistance.

Now, when the switch is closed, certain currents flow and the condenser begins to charge, and, therefore, part of the current is diverted from the arc. Since the current through the arc is decreased by this action, the voltage across the arc must rise, and it continues to rise as long as the condenser continues to charge. As soon as the condenser becomes fully charged, the arc voltage stops rising and the condenser begins to discharge itself through the arc.

When the discharge is complete, the cycle of charge and discharge repeats itself. The frequency determined by the constants of the inductance L and the capacity C determines the frequency of the high-frequency energy that can be obtained.

Audio Amplifying Systems
RESISTANCE-COUPLED AMPLIFIERS

A very satisfactory method of audio amplification employing resistance coupling. The usual resistance-coupled amplifier requires three stages in order to obtain sufficient gain to satisfactorily operate a loud speaker. The introduction of a new tube in order to achieve the necessary gain is of great convenience, and makes possible the achievement of some gain with sufficient amplification to drive a loud speaker. The new tube is known as the type 240 and data on it will appear on Laboratory Sheet No. 106.

Several factors must be given attention if satisfactory results are to be obtained from a resistance-coupled amplifier. The mere fact that it is a resistance coupled will not assure good quality. A poorly designed resistance-coupled amplifier is capable of creating as much distortion as can be obtained from a poorly designed amplifier of any other type. Some data regarding the constants of a resistance-coupled amplifier were given on Laboratory Sheet No. 106, March, 1927. The constants given were for an ordinary tube for use in the resistance-coupled amplifier with an amplification constant of about 20. For the new type high-mu tube, however, with an amplification factor of 0.9985, it is necessary to use somewhat different values of resistance. See, Laboratory Sheet No. 106.

The coupling condenser is a very important factor, and it is essential that this condenser have a very high insulation resistance, otherwise some of the B voltage will leak through the condenser to the grid circuit, and the amplifier will not function satisfactorily. In building up a resistance-coupled amplifier the best condensers should be used. It is essential that high-quality plate and grid resistances be used to prevent noise in the amplifier. Also, the plate resistor should be capable of carrying the plate current of the amplifier without overheating.

Another important point is the amount of plate voltage used. It should be realized that most of the plate voltage supplied to the amplifier is lost in the resistance in series with the plate circuit of the tube. For this reason, it is necessary that fairly high voltages be available in order that there will be sufficient voltage left at the plate of the tube to obtain satisfactory operation. At least 100 volts should be used, and it should preferably be 150. The C-grid voltages should be kept as low as possible. It will generally be found that in an ordinary resistance-coupled amplifier a C-grid voltage of about 3 volts will be necessary on the grid of the tube preceding the last tube, if the latter is of the 171 type. The C voltage on the first tube of the amplifier need not be more than one volt.

No. 97
RADIO BROADCAST Laboratory Information Sheet

No. 98
RADIO BROADCAST Laboratory Information Sheet

No. 99
RADIO BROADCAST Laboratory Information Sheet

Data on the "Universal" Receiver

Parts Required

On Laboratory Sheet No. 100 is given the receiver which was described in the December, 1929, issue of Radio Broadcast. In constructing this receiver, the following parts are necessary:

1. A four-section coil consisting of 13 turns of No. 26 d. s. c. wire wound at one end of a 21-inch tube.
2. A four-section coil consisting of 50 turns of No. 26 d. s. c. wire wound on the same tube as No. 1.
3. A twelve-section coil, L1, and L2 should be 1 inch.
4. A primary of interlace coil constructed in same manner as the detector center.
5. Secondary winding constructed in same manner as the detector center.
6. Secondary winding constructed in same manner as the detector center.
7. Regeneration condenser, 0.00005 mfd.
8. R.F. choice coil, made by winding 400 turns of 20 awg No. 5 brass wire on a 1 1/2" dry spool.
9. Two audio-frequency transformers.

Interstage double-circuit jack.
Single-circuit filament-control jack.
BATTERY.
Re-Fixed filament-control resistance for two 200-volt tubes.
Re-Fixed filament-control resistance for one power tube. One 0.00025 grid condenser with 3-megohm grid leak.
Four sockets.
Eleven phosphor bronze posts.

In operation, condensers C6 and C9 will control the tuning, and C10 will control the amount of regeneration. Various values of voltage storage condenser are tried on the plate of the detector tube, and that voltage used which gives the best regeneration. Frequency 253 volts is more satisfactory than 45. Make certain that the cathode battery voltage is not used on the grid of the r. f. tube, since the amplification obtained is of a considerably low order under such conditions. If there is any tendency toward regeneration or howling in the audio-frequency stages, reverse the connections to the primary of the transformer, T1.

INTERNATIONAL RESISTANCE CO. 2006 CHESTNUT STREET, PHILADELPHIA, PA.

1. Durham Resistors—600 Ohms, to 10 Megohms; standard brass end type.
2. Durham Grid Suppressor—250 Ohms to 3000 Ohms in steps of 100; standard brass end type.
3. Durham Poorer—1 ft. 250 to 1,000,000 Ohms; standard brass end type.
4. Durham Poorer—25 Watts, 500 to 250,000 Ohms; standard brass end type.
5. Durham Poorer—25 Watts, 500 to 250,000 Ohms; soldered end type.
6. Durham Poorer—5 Watts, 500 to 250,000 Ohms; soldered and tapped or screw-end type.
7. Durham Poorer—10 Watts, 250 to 250,000 Ohms; soldered end type.
8. Durham Poorer—25 Watts, 250 to 250,000 Ohms; soldered and tapped.
9. Durham Poorer—50 Watts, 250 to 250,000 Ohms; soldered and tapped.
10. Durham Mounting supplied in various lengths to carry any regular number of Resistors where quick change of resistance is necessary.
THREE years ago, Walter Van B. Roberts, famous the world over as the designer of the Roberts Circuit, wrote for Radio Broadcast a clear and accurate résumé of how radio receiving circuits work. It proved immensely popular and was issued in book form. The volume is finely printed on the best book paper, bound in heavy boards, gold stamped, contains 65 illustrations, and an especially valuable bibliography.

The whole background of radio theory is covered, in surprisingly brief and easily understood form. As clear as the best textbook, How Radio Receivers Work, by Walter Van B. Roberts is anything but a dry textbook.

Although this work was written more than three years ago, it is still popular and those who are looking for a simple presentation of the background of radio should order at once.

ORDER NOW—LIMITED SUPPLY

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W. VAN B. ROBERTS
Originator of six famous Roberts Circuits

Radio Broadcast Laboratories
Hammonton, N. J.

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I enclose my dollar for one copy of How Radio Receivers Work by Walter Van B. Roberts.

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RADIO BROADCAST

Doubleday, Doran & Co., Inc.

Garden City, N. Y.

Radio Broadcast Laboratories

Hammonton, N. J.

For a limited time the above book is being sold at the price of one dollar. It costs more to print it than the cost of paper and binding it. Yet we do not make a profit on it. We are willing to do this because it is the first book of its kind ever issued on the subject of radio receiving circuits. It is written for the beginner, the man who has never had a course in radio theory or who is in the service and wishes to learn how to use a radio set.

Radio Broadcast Laboratories

Hammonton, N. J.
No. 103

RADIO BROADCAST Laboratory Information Sheet

Audio Transformers

HIGH-IMPEDANCE PRIMARY NEEDED

This Sheet will explain why better quality is obtained from transformers with high-impedance primaries.

Drawing A shows how a transformer is connected in the plate circuit of a tube. Now, a voltage, E, on the grid of a tube is equivalent to a voltage of μEg (amplification constant times E) in the plate circuit of the tube. Also, the plate circuit of a tube acts like a resistance equal to value in the plate circuit. The transformer acts to obtain a B-14 type tube). These two facts were used in drawing the equivalent circuit diagram, B. In this diagram, E indicates the voltage AC available in the circuit. The transformer, Rp represents the plate impedance of the tube. In this transformer, the total voltage, μEg available in the circuit, must divide itself between Rp and T, the plate resistance. An increase in the percentage of the total voltage across the transformer, increases with increased impedance in the transformer. Now, the impedance varies with the frequency, becoming greater as the frequency rises and decreasing as the frequency becomes lower. It is evident, then, that the percentage of the total voltage across the transformer will also vary with frequency, and if this variation is great it will be a source of distortion. Practically, the result will be that, at the low frequencies where the transformer impedance is low, the voltage of the tube across the transformer, most of it being across the tube. As a result, the low frequencies will not receive as much amplification as do the moderate and high frequencies. The problem then is to design the transformer so that this variation of amplification with frequency is as small as possible consistent with economy of manufacture. The problem evidently comes down to one of designing a transformer to have as large an impedance as possible at the low frequencies, since the impedance increases with the inductance in the transformer by very efficiently so that the turns will have as much inductance as possible.

No. 104

RADIO BROADCAST Laboratory Information Sheet

Socket Power Units

VOLTAGE OUTPUT CURVES

At the present time, it is common practice in rating B-power units, to specify the voltages at various points in the circuit which we will deliver from the high-voltage tap. These data are obtained by connecting a variable resistance, in series with a milliammeter, between the negative B and the terminal giving the highest voltage, and then measuring the output voltage with different values of resistance through the milliammeter. The data may be collected in the form of a table or a curve may be plotted. It is best to plot a curve for, from it, we can determine the voltage at any current drain. Also, the slope of the curve gives us visually an idea of how constant the voltage is.

If full benefit is to be obtained from such curves, it is essential that we thoroughly understand what they signify. We must first determine the total plate-current drain of our receiver. This information can then be obtained by connecting a milliammeter in series with the negative B lead, where we illustrate the total plate current. Suppose the reading to be 35 milliamperes; the value of current is now located on the curve and we find that the corresponding plate voltage (for this particular case) is 135 volts. This is the maximum voltage that the socket-power unit will supply at 35 milliamperes. If you require a maximum of 135 volts for your receiver, then the unit is satisfactory. If you cannot use as much as 135 volts and there is no adjustment on the device to lower this voltage, then the unit is not satisfactory; or you might want to use a 171 type tube with 180 volts and in this case also the unit will be unsatisfactory for it can only deliver 135 volts at the requisite current drain.

The curve tells us nothing concerning the voltages supplied by the other terminals on the power transformer. The impedance of low frequencies depends upon the inductance. The larger the inductance the greater the impedance.

No. 105

RADIO BROADCAST Laboratory Information Sheet

Measuring R. F. Resistance of a Coil

NECESSARY EQUIPMENT AND PROCEDURE

The job of measuring radio-frequency resistance is not an especially difficult one, although it requires considerable apparatus. The circuit diagram is given on this Sheet. The apparatus used should have the following characteristics:

Oscillator—This represents a source of radio-frequency energy which should be adjusted to the frequency at which the measurements are to be made. It should have plenty of power. In the Laboratory a 210 tube will give considerable output, but it is doubleously possible to use a 12AT7 as an oscillator with about 100 volts d-c. applied to the plate. An oscillator is so arranged that adjustment in the test circuit should produce no change in the energy delivered by the oscillator.

A—This is a radio-frequency milliammeter with a range of about 200 milliamperes or preferably somewhat less. It may be a hot-wire or thermocouple meter, or an ordinary crystal detector used with a low-range d-c. milliammeter.

C—The condenser should be a very carefully constructed one because it is essential that its resistance be low and constant. It should preferably be a laboratory type instrument although a well-made receiving condenser can be used.

R—This resistance must be continuously variable and must be non-inductive. A decade resistance box is well suited for this purpose.

Pick-up coil. The pick-up coil functions to pick up energy from the oscillator and feed it into the test circuit. It may consist of just a few turns of wire coupled to the oscillator so as to give a good detection on the meter. A coil under test circuit is quite simple. Start with zero resistance at R and once the test circuit has been made as complete as in the oscillator or in the position of the pick-up coil. The oscillator should be turned on and the condenser varied until the circuit is in exact resonance, this condition being indicated by a maximum reading noted on meter. Points 1 and 2 are now short circuited and the condenser varied as is to again bring the circuit into resonance. The reading of the meter will now be greater than before because the resistance of the coil under test is no longer in the circuit. Now add resistance to the circuit at R until the meter reading is decreased to the same value as was noted above, and under such conditions the resistance R is equal to the r.f. resistance of the coil under test.

PAC 2 List Price $175.00 without tubes

PAC2, a combined 2-stage transformer coupled amplifier and A, R & C Eliminator is ideal for use with an AC or DC-inking unit. Its external voltages are 45, 90 and 135 volts. Price $175.00 without tubes.

All units are designed to meet AIEE standards and Underwriters’ requirements. Write for bulletin 558 which more fully describes these units.

SAMSON ELECTRIC COMPANY

MAIN OFFICE: Manufacturers CANTON, MASS. Since 1882

Symphonic and Symphonic Push Pull Transistors—having approximately 7 watts output power.

PAM 16 & 17 List Price $125.00 without tubes

A "Pam" Amplifier is a Sound Investment

Pam 16 for magnetic and Pam 17 for dynamic type speakers, for which the latter supplies a flat, wide band, all electric, amplifier—that utilizes AC tubes and Symphonic and Symphonic Push Pull Transistors—having approximately 7 watts output power.

PAM 19 & 20 List Price $175.00 without tubes

Pams 19 & 20 are 3-stage transformer coupled amplifiers similar to Pam 16 & 17, but have 24 to 3 times the undistorted power output.
40 RADIO BROADCAST'S DATA SHEETS

No. 106 RADIO BROADCAST Laboratory Information Sheet
The 240 Type Tube

GENERAL CHARACTERISTICS

THE 240 type tube is designed for use in resistance-coupled amplifiers and under proper conditions will give an effective amplification of about 20 per stage. The plate resistor used with this tube should have a value of 260,000 ohms and the B and C voltages should be 180 volts or 160 volts and 3 or 1.5 volts respectively. The coupling condensers should have a value of 0.05 mfd. and the grid leak resistance should be of 2 megohms; these values are correct when the tube is used as an amplifier. It can also be used as a C-battery type detector in which case the C voltage should be 3 volts for a plate voltage of 125 or 1.5 volts for a plate voltage of 180. The plate resistor, coupling condenser, and grid leak should have the same values as given above.

The general characteristics of this tube are as follows:

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<th>Characteristic</th>
<th>Value</th>
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<tr>
<td>Filament Voltage</td>
<td>5.0 Volts</td>
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<tr>
<td>Filament Current</td>
<td>0.25 Amperes</td>
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<td>Maximum Plate Voltage</td>
<td>180 Volts</td>
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<td>Amplification Constant</td>
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<td>Plate Impedance</td>
<td>150,000 Ohms</td>
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<tr>
<td>Plate Current</td>
<td>0.2 Milliamperes</td>
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This tube can be used in any existing resistance-coupled amplifier provided the resistances used are of the proper value and the tubes are supplied with the proper, A, B, and C voltages. It is not possible to use this new tube in a transformer-coupled amplifier because its high plate impedance will cause the transformer to have a rather sharp peak at some frequency. This, however, makes the tube very satisfactory as an amplifier for, e.g., reception in short-wave receivers where we are interested in obtaining high amplification around 1000 cycles and very poor amplification at all other frequencies. The tube can also be used as a detector in a short-wave receiver.

No. 107 RADIO BROADCAST Laboratory Information Sheet
Neutralization

EFFECTS OF MALADJUSTMENT

AT THE present time there is only one known way whereby a very high quality high-frequency amplifier can be obtained, and that is by using several well-designed tuned radio-frequency amplifiers with each stage properly neutralized. Manufactured receivers are neutralized at the factory and consequently the problem of neutralizing is receiver or the effect of improper neutralization does not generally concern those who buy their receiver ready made. The home constructor, however, must neutralize his own receiver, and for this reason it is rather important that the effect of improper neutralization be known.

The first and most obvious manifestation of incorrect adjustment of the neutralizing device is oscillation in some or all of the radio-frequency circuits. These oscillations as a general rule become more severe as the frequency is increased, and a loud squeal will be heard as the tuning controls are adjusted to receive some station in the neighborhood. Such an effect will make it difficult for the user of the receiver to obtain satisfactory reception and the oscillations will be radiated from the antenna attached to the receiver and cause interference on other receivers located in the neighborhood. Such oscillations can be prevented by correct adjustment, and it is essential that the proper setting be determined in order to make it possible to obtain best results from the receiver.

A second detrimental effect of maladjustment of the neutralization is poor quality, which is generally due to the existence of too much regeneration. The quality under these conditions will generally sound drummy, indicating that the various frequencies in the carrier are being unequally amplified by the radio-frequency amplifiers. To preserve good quality, the radio-frequency amplifiers must amplify without distortion a band of frequencies extending about 5000 cycles above and 5000 cycles below the carrier frequency, and this condition does not exist unless proper neutralization is obtained.

Another effect of improper neutralization is to cause one or more of the tuned circuits in a singlecontrol receiver to be thrown out of synchronism so that the set loses a great deal of its sensitivity, and as a result it is not possible to tune in distant stations with satisfactory volume. These three major effects of improper neutralization indicate how essential it is that neutralization be always carefully and completely accomplished. There are several satisfactory methods of neutralizing a receiver, and information regarding them can be found on Laboratory Sheet No. 38, published in the October, 1928, issue.

No. 108 RADIO BROADCAST Laboratory Information Sheet
High Voltage Supply for 210 Type Tube

THE DOUBLE TRANSFORMER METHOD

If high voltages up to 400 volts are required for operation of a 210 type power tube, then it is generally best to use a B power unit incorporating a 216-B single-wave rectifier tube. This tube is capable of operating satisfactorily at the high transformer voltages which must be used. It is possible, however, by using a somewhat complicated arrangement, to obtain the high voltage by using low-voltage rectifiers such as the Raytheon and U.C.S. An arrangement whereby 400 to 450 volts can be obtained using two gaseous rectifiers is shown in the drawing on this Sheet. Two power transformers, T1 and T2, are needed, each supplying about 220 volts each side of the tap. These transformers are connected into the circuit as shown and supply the two rectifiers which in turn feed a common filter assembly. The maximum permissible current drain is 20 milliamperes per Raytheon type B tubes and 35 milliamperes using type U.C.S. tubes. Condensers C1, C2, C3, and C4 each have a capacity of 0.001 microfarads. C1 and C3 are of 2-mfd. capacity, and C2 and C4 of 0.05-mfd. All the condensers should have a working voltage of 1200 volts d. c.

Filament current for the 210 tube should be obtained from a separate filament transformer supplied with 750 volts d. c.

Td supplied by the transformer should be capable of supplying 12 amperes at 7.5 volts. The transformer should be tapped at the center as shown and a 1500-ohm resistance, R8, connected between it and the negative B of the filter system. This resistance will supply C bias to the tube. Its bypass condenser should have a value of 2 mfd. A 50,000-ohm 0.001-mfd. resistance should be connected from B+ to H. The unit is only to supply B potential to the tube. But it is also to be used to supply V10 volts as described above, and the receiver output should be shunted by several fixed resistors with taps at various points to obtain the desired voltages.

A VERSATILE TUBE for Your Laboratory

Of course you are familiar with Raytheon B.H., the rectifying tube, which is original equipment in more than a hundred different makes of power units.

But do you know that its long life, and efficient and uniform performance have made Raytheon one of the most widely used tubes for laboratory work?

Among the many uses, to which this highly versatile tube is being put, may be mentioned:

1. Supplying oscillator circuits.
2. Charging storage "B" batteries.
3. Supplying electro-magnet and relay field currents.
4. Supplying field currents for electro-dynamic speakers.
5. For use in series to supply a high voltage source in testing or amplifier equipment.

Those interested in technical data are invited to write to our Technical Service Department for further information.

Raytheon Manufacturing Company
Kendall Square Building
CAMBRIDGE, MASS.
No. 109  RADIO BROADCAST Laboratory Information Sheet

The Threshold of Hearing and Feeling in the Ear

ENERGY REQUIRED FOR AUDIBILITY

A GREAT many important experiments in sound have been made in the various large laboratories. An interesting experiment is to determine how much energy is required by the ear in order to just hear tones of various frequencies between about 30 and 5000 cycles. Data of this sort can be plotted on a curve, a typical one being given on this Sheet. Such a curve is called a curve of "threshold audibility" because it indicates the amount of sound energy required to just produce an audible sound. At 30 cycles a sound pressure of somewhat more than one dyne per square centimeter is required to produce an audible response, while at 2000 cycles only about 0.0003 dynes per square centimeter are required to produce an audible sound. The sound pressure required to produce a sound of minimum intensity is fairly constant between about 500 and 5000 cycles. Good speech articulation can be attained within a frequency range of 250 and 2500 cycles; this band can, in fact, be narrowed to exclude all frequencies below 500 cycles and good articulation will still be retained. In the reproduction of music, however, it is necessary to utilize a much wider band having an upper limit of 5000 or 6000 cycles and a lower limit of about 30 cycles.

There is also a upper limit of sound pressure at which there is produced a sensation of feeling in the ear and it serves as a practical limit to the range of auditory sensation. At low frequencies the two curves, feeling and hearing meet each other, which indicates that these frequencies give a sensation of feeling which is difficult to distinguish from a sensation of hearing.

The power in microwatts in each square centimeter of the sound wave under average conditions is related to the effective value of the pressure in dynes as follows:

\[ \text{Power} = \left( \frac{\text{Pressure in Dynes}}{0.025} \right)^2 \]

Using this formula we can calculate the average power required to produce a minimum audible sound at frequencies between 2000 and 6000 cycles, which will be found to be about \(4 \times 10^{-8}\) microwatts per square centimeter.

---

No. 110  RADIO BROADCAST Laboratory Information Sheet

Dry-Cell Tubes

BEST FILAMENT VOLTAGE

ALTHOUGH dry-cell tubes are generally operated with 3 volts on the filament, somewhat better results are obtained if 3.3 volts is used instead. The two solid curves on the accompanying diagram are obtained by measuring the plate current at various values of negative grid bias with 3.0 and then 3.3 volts across the filament. If the tube is functioning properly this curve will be a straight line over most of its length. The 3.0 volt curve slopes off at low values of grid bias and this indicates that the filament emission is too low and a signal would be distorted. The 3.3 volt curve, however, is straight over a large portion of its length and therefore this same tube with somewhat higher filament voltage is capable of amplifying without distortion.

The two dotted curves show the plate impedance of the tube with 3.0 volts and then with 3.3 volts on the filament. With 3.0 volts, and therefore a low filament emission, we obtain an erratic plate impedance curve, which rises to values as high as 80,000 ohms at zero grid voltage. The plate impedance curve taken with 3.3 volts again indicates the value of using this voltage, for it shows the plate impedance to be comparatively constant and low over a greater part of its length, and this is as it should be.

This recommendation that 3.3 volts be used on the filament is the result of many tests made in the Laboratory, and the Cunningham Tube Company has also recommended that this voltage be used.

---

ADVERTISMENT

Circuit Diagram of The Skyscraper

---

FERRANTI Audio Frequency Transformers

"In the FERRANTI Audio Frequency Transformers the primary inductance is made large by using a great number of primary turns, a core of large cross section and a short mean core path. The mean core path is made as short as possible and is at the same time not short enough to make the D. C. saturation appreciable. The core loss has been made negligible by the use of a laminated core of ample cross-section with properly insulated laminations of high resistance alloy steel. The leakage inductance was made very small by interleaving the secondary coil between two sections of the primary coil. The mutual capacity is kept low by the use of air as the principal insulation. The dielectric constant of air is 1 as against 3 or 4 for paper and oilied cambric insulators."

Send 15c in coin for copy of the FERRANTI 1929 Year Book from which the above is an abstract.

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List Price $95.00
Instructions separate net price $1.00

FERRANTI, Inc.
130 West 42nd Street
New York, N. Y.
No. 113 RADIO BROADCAST Laboratory Information Sheet

Output Circuits

**THREE POSSIBLE CIRCUITS**

**In** this sketch on this Sheet are shown three output arrangements that can be used to couple a loud speaker to a power tube in order to prevent the direct current in the plate circuit of the power tube from passing through the windings in the loud speaker and affecting its satisfactory operation. In sketches "A" and "B" the introduction of the choke coil, "L," should be at least 60 henries and these coils should provide such low resistance as to prevent any great loss in voltage which would occur if the resistance was very high. A good unit should not cause a loss in voltage of more than 2 or 20 volts and this means that its d.c. resistance must not be greater than 75 ohms. The blocking condensers, "C," should have a capacity of from 2 to 4 mfd.

The larger size theoretically gives somewhat better reproduction but practically little difference will be noticed with most loud speakers whichever size is used.

The arrangement shown at "A" has the advantage that, if the condenser breaks down, it will not result in any damage to the loud speaker because a breakdown in the condenser will merely cause the loud speaker to be shunted across the output choke "L," whereas, with arrangement "B," a breakdown of the condenser will cause the b battery to be short-circuited through the loud speaker and it is possible that the latter will be burned out. A disadvantage of arrangement "A," is that the a.c. current flowing through the loud speaker must flow through the B supply in order to return to the negative filament and, as a comparatively small amount of resistance is supplied in this manner, it frequently causes a howl in the amplifier. In the arrangement shown in "B," the a.c. currents in the loud speaker do not return directly to the negative filament and do not have to traverse the B power unit; consequently, with this latter arrangement, there is less danger of oscillation in the audio amplifier.

In one particular case, during experiments in the Laboratory, a resistance of 37 ohms in the B power unit, using circuit "A," produced continuous oscillations, whereas a resistance of 600 ohms was necessary in circuit "B" before oscillations were produced.

**The arrangement at "C" shows an output transformer which is also a satisfactory method of coupling a loud speaker to a tube. It is essential, however, that the transformer be very carefully designed for the particular job; magnetic saturation because it must carry comparatively large direct current.**

No. 114 RADIO BROADCAST Laboratory Information Sheet

**The Transmission Unit**

**DEFINITION**

A NY electrical system having anything to do with the transmission of electrical energy which is finally to be converted to sound energy should have its performance rated in some manner which bears relation to the sensitivity of the ear.

Two audio amplifiers might give power outputs of 800 and 1000 milliwatts, and it appears from these figures as though the second amplifier would be capable of giving a considerable increase in volume over that obtained from the first amplifie, but actually this would not be so; the difference between the two amplifiers could hardly be detected by the ear.

Evidently it would be of advantage to express the relation between the power outputs of the two amplifiers by some unit which would indicate their relative value as measured by the ear. The telephone companies have worked out such a unit, known as the transmission unit, abbreviated "t.u." It is possible for the ear to just distinguish the difference between two powers that differ in intensity by 1 t.u.

The two powers mentioned above, 800 and 1000 milliwatts, are in the ratio of 1 2/3 t.u. The t.u. difference between these two powers is equal to ten times the natural logarithm of the ratio of the two powers:

\[ \log \text{t.u.} = \log \frac{1000}{800} = \log 1.25 = 0.097 \]

The ratio in this case is 1.25 and the natural logarithm is 0.097, which, multiplied by ten, gives 0.97 t.u. The minimum perceptible change is 1 t.u. and therefore the difference between the two amplifiers would not be audible.

The equation given in the preceding paragraph gives the t.u. when two powers, or their ratios, are known. If instead of powers we deal with voltages, \( V_1 \) and \( V_2 \), then the formula is:

\[ t.u. = \log \frac{V_2}{V_1} \]

When using currents, \( I_1 \) and \( I_2 \), the equation is:

\[ t.u. = \log \frac{I_2}{I_1} \]

The logarithm of the ratio of two voltages differing by 12% per cent., is 0.05 and this gives 1 t.u. Therefore, if two audio transformers differ in performance by 12% per cent., they should give good results because a 1 t.u. change is not audible to the ear.

The natural logarithm of numbers can be found by using a slide rule or they can be determined from tables of logarithms which are frequently found in the appendix of text books.

No. 115 RADIO BROADCAST Laboratory Information Sheet

**Wave Traps**

**DIFFERENT TYPES**

**IN** MANY cases where difficulty is experienced in eliminating the interference from a nearby powerful broadcasting station it will be found advantageous to use a wave trap in the antenna circuit.

A wave trap is a simple device consisting of a condenser and a choke coil in parallel and is inserted to eliminate any sharply resonant frequencies within a given frequency range.

One of the most important characteristics of a wave trap is its effective length. The effective length of a wave trap is the length of wave in the medium used which is attenuated by the wave trap for a given frequency.

If the medium is air, the effective length of a wave trap is given by:

\[ L_a = \frac{1}{n} \]

\[ n = \text{wave number} \]

\[ c = \text{velocity of light} \]

\[ f = \text{frequency} \]

\[ L_a = \frac{c}{nf} \]

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\[ c = \text{velocity of light} \]

\[ f = \text{frequency} \]

\[ L_a = \frac{c}{nf} \]
No. 116  RADIO BROADCAST LABORATORY INFORMATION SHEET

Static

whereas the desired signals are not balanced out. In Morcroft's book, Principles of Radio Communica-
tion, it is suggested that one of the most promis-
ing lines for the development of a static eliminator
has to do with a vacuum-tube detector which can
only produce a limited response to static and
therefore even with very heavy static the receiver
response cannot be more than the definite basic
response of the tube.

Reception is also interfered with to a great ex-
tent in many localities by sounds produced by
electrical apparatus, in which category can be
placed the interference caused by various electrical
motors and generators, x-ray apparatus, oil burn-
ers, precipitators, etc.

Their elimination is best accomplished at the source
of the trouble by means of filter circuits, such as
those described in Laboratory Sheet No. 77, in
the March, 1927, Radio BROADCAST.

At the present time it appears that the best
method to overcome natural static is to use a
receiver in combination with a loop or a very short
antenna, because with a loop or short antenna a
high signal-to-static ratio can be obtained. Also, to
prevent serious interference with broadcast pro-
grams, high power at the transmitting station
is coming into more common use so that even under
fairly bad conditions of static satisfactory reception
can still be had.

No. 117  RADIO BROADCAST LABORATORY INFORMATION SHEET

Super-Heterodynes

THE OSCILLATOR

In a super-heterodyne receiver it is necessary to
have one tube functioning as an oscillator and func-
tioning at a very high frequency energy which, in
combination with the incoming signals, will produce
a third frequency capable of being amplified by
the intermediate frequency amplifier. The amplitude
of the locally generated oscillations, in comparison
with the incoming signals, has a very definite effect
upon the reception of the signal which is finally
detected and some care should therefore be taken in
adjusting the circuit for most efficient operation,
that of lowest signals.

In sketch "A" is a circuit used, probably, in
a majority of super-heterodynes. It has the dis-
advantage that both sides of the variable condenser
are at high potential and therefore some hand-
capacity effect will be experienced.

In sketch "B" is shown an oscillatory circuit
which is not open to the disadvantage of circuit
"A" since the plate of the variable condenser
are at high potential and therefore some hand-
capacity effect will be experienced.

In sketch "B" a condenser is used in the circuit,
probably, in a majority of super-heterodynes. It has the dis-
advantage that both sides of the variable condenser
are at high potential and therefore some hand-
capacity effect will be experienced.

This "B" makes it possible to adjust the circuit
in actual practice. In this circuit the rotor plates
of the variable condenser are connected to the low-potential
side of the grid coil instead of across the entire coil.
The "low" end of the grid coil connects to the fila-
ment and is therefore at ground potential and conse-
quently there is no hand capacity. If a 0.0005-mfd.
variable condenser is used, then coil "L" should
be placed between coils until the desired perfor-
mation has been obtained. This circuit will not
produce a process of static.

The "low" end of the grid coil connects to the fila-
ment and is therefore at ground potential and conse-
quently there is no hand capacity. If a 0.0005-mfd.
variable condenser is used, then coil "L" should
be placed between coils until the desired perfor-
mation has been obtained. This circuit will not
produce a process of static.

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AERIAL PRODUCTS INCORPORATED

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* Data Sheet "No. 117" originally contained one index and was purposely omitted.
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(Helical Wound)

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Samson Helical Wound Chokes hold this field exclusively because their patented winding makes them act like chokes at all frequencies and not like by-pass condensers at some frequencies. This wind ing reduces distributed capacitance effect to a negligible minimum and prevents any self resonant points.

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You will desire to know how to apply R.F. and A.F. chokes to 17 popular circuits or your own receiver as illustrated in our Make-Em-Better Sheet. Send 5c, to cover cost of mailing.

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No. 3 Samson A. F. Choke (3 henrys) $3.25

Those who desire to know how to get supreme coil efficiency can obtain our new "Inductance Units Bulletin" which will be sent on receipt of 10 cts. to cover cost of mailing.

Our book "Audio Amplification" accepted as a manual of audio design by many radio engineers contains much original information of greatest practical value to those interested in bettering the quality of their reproduction. Sent upon receipt of 25 cts.

SAMSON ELECTRIC COMPANY

MAIN OFFICE: Manufacturers
CANTON, MASS. Since 1882
Factories at Canton and Water-
town, Mass.
No. 121

Radio Broadcast Laboratory Information Sheet

The Hertz Antenna

CHARACTERISTICS

One of the most common antenna systems used by amateurs is the Herz system. This antenna, in its simplest form, consists of two straight wires spaced diametrically opposite each other as indicated in the drawing on the accompanying curve. The length of the wires is equal to a whole number of wavelengths at the frequency for which the antenna is to be used. The relation between the length of the antenna system and the fundamental wavelength is constant. The length is 1/2 if the antenna would be of such a size as to have a fundamental wavelength equal to 40 meters. If supplied with energy at a frequency corresponding to 40 meters, however, the antenna would radiate energy at this frequency very efficiently even though its natural wavelength is 120. If such a system of transmission were to be used, the length of the antenna and the counterpoise would each be 93 feet.

No. 122

Radio Broadcast Laboratory Information Sheet

Testing Radio Receivers

FEATURES TO CONSIDER

It is obviously of distinct advantage to test radio receivers in accordance with some standardized test procedures so that the results obtained from different receivers can be readily compared. If such a method is used the manufacturer will be able to quote his receiver information which will tell him definitely just how his product compares with those of other makes and also the buyer of a receiver will have certain definite data upon which to base his decision in buying a receiver. Considerable information on methods of testing radio receiving sets is given in the Electronic Trade Journal of the Bureau of Standards, No. 256. In this paper it is suggested that the following tests be made on a receiver: (A) Frequency range, (B) Vibration test, which determines how well the set has been constructed mechanically and whether it will be able to withstand the ordinary shocks obtained in transportation, (C) Sensitivity, (D) Selectivity. These tests are especially effective in indicating how well the set has been engineered from an electrical standpoint. A test should also be made of fidelity, to determine how well the receiver is capable of reproducing voice and music.

No. 123

Radio Broadcast Laboratory Information Sheet

Characteristics of 171 Type Tube

STATIC AND DYNAMIC

On Laboratory Sheet No. 124 are given several curves for the 171 tube. It will be noted that one curve is marked static and another dynamic. The dynamic characteristic is, as its name implies, a curve indicating how the tube will function under all operating conditions. The static characteristic, although valuable in the general case of the grid characteristics of a tube, gives no indication at all of the tube's actual performance under such operating conditions as tube always operates with a certain load in its plate circuit and consequently a curve indicating the tube's performance should be made with some load in the plate circuit. The curve of the dynamic characteristics with its load line indicates how the tube's performance would be if it were operated with an external load.

The other curves on Sheet No. 124 give dynamic characteristics with different resistances in the plate circuit. Curve No. 1 was made with 1000 ohms resistance, No. 2 with 2000 ohms, and No. 3 with 9000 ohms. It will be noticed that as the resistance increases the straight portion of the curve becomes greater and greater. The curves shows that the grid voltage a tube needs for the plate current to be any amount below the plate current of the plate circuit is determined by the working point of the tube and the grid current is made by increasing and decreasing the grid voltage about this average value. It is necessary to take the curves to adjust the plate voltage each time so that with the different resistance the same plate current is obtained at 40 volts on the grid.

for 1929

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No. 124
Curves of the 171 Type Tube

No. 125
Wave Traps

Three Circuits

If the tuning condenser C has a capacity of 0.0005 mfd., with a 1000 ohm condenser coil L, it should consist of 60 turns. With either a 500 ohm condenser coil or 1000 ohm condenser coil L, it may consist of about 15 turns wound at the b end of the secondary coil. With arrangement B, taps should be made at about every 10 turns.

No. 126
Condenser Reactance

In many calculations it is necessary to know the reactance of a particular condenser at some frequency, and for this reason, a Laboratory Sheet No. 126 is given a table of equivalent reactances for certain condenser capacities between 0.001 and 10 mfd., at frequencies from 60 to 1,000,000 cycles. From the formula given herewith it is evident that the reactance of a condenser is inversely proportional to the capacity of the condenser and in nearly proportional to the frequency. Doubling the size of the condenser therefore gives half the reactance, and doubling the frequency of the current also halves the reactance of the condenser. Remembering these two facts it is a simple matter to calculate mentally the reactance of almost any capacity not given in the table on Laboratory Sheet No. 126. For example, a 0.5 mfd. condenser at 100 cycles has 0.5 of the reactance of a 1 mfd. condenser at 100 cycles. Since the reactance of the latter size at 100 cycles is 1600, then the reactance of a 0.5 mfd. condenser must be 800 divided by 2, or 500 ohms. A 0.001 mfd. condenser at 1,000,000 cycles has a reactance of 100 ohms. A 0.0001 mfd. condenser at this frequency therefore has a reactance of 1000 ohms, and a 0.01 mfd. condenser likewise has a reactance of 16 ohms.

Condenser Reactance

10F
8.26 P.E.

Where F is the frequency in cycles per second and C is the capacity of the condenser in microfarads.
No. 127  RADIO BROADCAST Laboratory Information Sheet

Condenser Reactance

<table>
<thead>
<tr>
<th>Condenser Capacity</th>
<th>Reactance in Ohms at Various Frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>in Mhos.</td>
<td>60</td>
</tr>
<tr>
<td>0.001</td>
<td>252</td>
</tr>
<tr>
<td>0.01</td>
<td>252</td>
</tr>
<tr>
<td>0.5</td>
<td>252</td>
</tr>
<tr>
<td>2.0</td>
<td>252</td>
</tr>
<tr>
<td>8.0</td>
<td>252</td>
</tr>
<tr>
<td>10.0</td>
<td>252</td>
</tr>
</tbody>
</table>

This table shows how the reactance of various capacities varies with different frequencies. The reactance of a condenser varies inversely with its capacity and directly with the frequency. See Laboratory Sheet No. 126.

No. 128  RADIO BROADCAST Laboratory Information Sheet

B Power Units

DESIRABLE CHARACTERISTICS

A B-POWER unit is essentially a device to supply plate voltage to a radio receiver unless such a unit has several characteristics besides the ability to supply proper voltages that are important in determining how satisfactorily it will operate. Modern batteries for the plate supply of a receiver can barely be improved on. Their voltage is constant, they are perfectly quiet in operation, and leave in the receiver a noise of practically zero potential. The expense of operating a multi-tube receiver using new tubes from batteries is considerable, however, but a B power unit, properly designed, affords an excellent source of high plate potential at moderate cost.

What are the desirable characteristics of such a unit? It must first of all be capable of supplying the proper voltages to a receiver. Either insufficient or excessive voltage will adversely affect the operation of a receiver in many cases and it is therefore essential that some care be taken to make certain that the voltages being supplied are correct.

The power unit must deliver those voltages with a minimum of a.c. hum. Low hum output is only obtained with a properly designed transformer and filter system. The various filter chokes should be shielded so that magnetic coupling between them will not be possible and it is also necessary that some means be used to electrostatically shield the high-voltage secondary windings from the primary winding to prevent any line noise from the power mains getting into the filter system, and making the output of the unit noisy. This shielding between the primary and secondary must be accomplished by means of a grounded copper shield between the primary and secondary windings or the shielding may be accomplished quite effectively by placing the filament winding, supplying the power tube, between the primary and high-voltage windings. The filament winding, being at ground potential, therefore acts as a very effective shield. A noisy plate supply unit generally indicates the lack of proper magnetic shielding, or improper filtering. A third desirable characteristic of a power unit is good regulation, which determines how much the output voltage will change with changes in the amount of current being supplied by the unit. A particular plate supply had 60 volts at the 90-volt tap with a load of 10 mA. If, however, the regulation was poor and your receiver only required 4 mA, the 90-volt tap, the actual voltage at this tap might rise as high as 120 volts; if the unit had good regulation the voltage would not be more than 96 at a load of 4 mA. Power units with poor regulation frequently cause receivers to "motor boat" or distort the signal in some other way, and good regulation, i.e., small variation of output voltage with output load, is therefore a very desirable characteristic.

No. 129  RADIO BROADCAST Laboratory Information Sheet

The Type 874 Glow Tube

HOW IT FUNCTIONS

The Type 874 tube is a special voltage regulator designed for use in B power units to maintain the voltages, supplied by the unit, constant. An ordinary B power unit operated without a glow tube has a comparatively poor regulation, i.e., the voltage changes considerably with changes in the amount of current being drawn from the unit. It would obviously be of decided advantage if the voltage could be made to remain practically constant at all loads. The power unit could then be used with any receiver irrespective of the amount of current being drawn by it, within reason, with the knowledge that the actual voltages designated on the binding posts of the B device were being supplied. How the glow tube functions to maintain the voltage constant may be understood by reference to the curve A. This curve is plotted by measuring the voltage across the glow tube with various load currents and it should be noted that the voltage across the tube is practically 50 at all loads up to and including 40 mA. In ordinary operation, when there is no current being drawn from the 90-volt tap of the tube circuit is about 45 milliamperes. Then, if current is drawn from a receiver from the 90-volt tap, which would ordinarily cause the voltage to go down, the current through the glow tube automatically decreases, providing for the current required by the set. The voltage thereby maintained at once rises to 90. Curve B illustrates the curve of output voltage that might be obtained from a B power unit not using a glow tube. At a load voltage of 125, while at a load of 10 mA, the voltage drops to 90. If, however, the receiver requires 50 milliamperes, the actual voltage available would be only 60 volts.

A New Power Unit

Thordarson introduces a new number to their line of power compacts for the home constructor. The R-280 type is designed for power amplifiers using either a single or two 171 power tubes. Rectification is supplied through a single UX-280 full wave tube. The Power Compact R-280 includes a high voltage supply, a 5 volt filament supply for the power tubes and two 10 henry filter chokes. Capacity, 85 M.A. Terminals are arranged to provide great ease of assembly of complete amplifier.

R-280, list price $17.00.

THORDARSON R-171 POWER COMPACT

A unit similar to the R-280, designed for one or two 171 power tubes, employing a Raytheon 8H Rectifier. Buffer condensers are also included in this compact. R-171, list price $15.00.

THORDARSON R-210 POWER COMPACT

This compact is similar to the types above, but is designed to operate through a UX-281 type half wave rectifier and supplies a single UX-210 power tube as well as plate voltages for the receiver.

R-210, list price $20.00.

THORDARSON T-2098 POWER TRANSFORMER

A power supply transformer designed to supply A, B, and C current to two 171 power tubes and plate current for the receiver. Rectifies through two UX-281 tubes.

T-2098, list price $20.00.

THORDARSON T-2099 DOUBLE CHOKE

This choke unit consists of a two individual choke coils in one compound shielded case. Each choke 30 henries, 150 M.A. Designed for use with transformer T-2098. T-2099, $14.00.

THORDARSON ELECTRIC MFG. CO.

Transformer Specialists since 1895

Huron & Kingsbury Sts., Chicago
Authorities Agree

that the best choice for television reception is the type of amplifier that can be built from the

LYNCH TELEVISION Amplifier Kit

WITH this precision-built kit you can assemble at minimum trouble and expense an efficient amplifier for securing quality reproduction in your television reception apparatus.

The audio amplifier is an extremely important part of television receivers. Where the signal to be received contains frequencies of from 18 to 20,000 cycles, the audio amplifier must be able to amplify all frequencies within these limits. Such an amplifier is available at your dealer in the Lynch resistance coupled amplifier kit.

LYNCH PRODUCTS

are universally accepted where the Best is Standard. They include Filament Equalizers, Non-inductive and non-capacitave Supersors, Dynomonic Resistors, Leak Proof Single and Double Mountings and the popular Lynch Deck which simplifies receiver construction.

Your dealer has a Lynch precision-built resistor for every resistance need. Send for free book.

ARTHUR H. LYNCH, INC.
General Motors Building
1775 Broadway, at 57th Street
New York, N. Y.

No. 130

Data on Honeycomb Coils

<table>
<thead>
<tr>
<th>No. of Turns</th>
<th>Inductance, at 500 Cycles, in Millimicrohenries</th>
<th>Natural Wavelength, Meters</th>
<th>Distributed Capacity in Megohms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
<td>120 to 245</td>
<td>0.0005-50,000 Condenser</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>120 to 245</td>
<td>0.001 Meg. Condenser</td>
</tr>
</tbody>
</table>

No. 131

Resistance-Coupled Amplifier

DATA ON CONSTANTS

ON LABORATORY SHEET No. 132 is given a circuit diagram of a resistance-coupled amplifier using the new type 500 high-mu tube. (Cunningham type 340). To obtain satisfactory operation from such an amplifier it is essential that several points be given careful consideration. In the first place it is essential that excessive C's or R's not be used on any of the high-mu tubes. The following values should be used in combination with the voltage shown in the circuit diagram to prevent overloading; 1 volt on the first stage, 3 volts on the second stage, and 40.5 volts on the 17th power tube. The second consideration of great importance in the construction of such an amplifier is that the coupling condensers, C6, C8, and C10, be of the best quality that can be obtained. Even a small amount of leakage across the condenser, due to faulty insulation, will permit some of the plate potential to leak through it to the grid of the next tube and this will not only cause distortion but very frequently will make the amplifier absolutely inoperative. Use only the best of mica condensers.

It is, of course, also essential that the plate and grid resistance be nonexistent in operation but it is not necessary that they be exactly of the values given in the circuit. A variation of ten or twenty per cent, in these values is quite unimportant. The plate supply for the amplifier may either be a well-constructed B power unit or batteries. No trouble whatsoever should be experienced when operating the unit from new batteries, but it is possible that "motor-boating" troubles will develop when the unit is operated using some B power units. The overall gain is comparatively high and difficulties of this sort become more pronounced as the amplifier is loaded.

No. 132

Resistance-Coupled Amplifier Circuit

Data concerning resistance-coupled amplifiers appear on Laboratory Sheet No. 131.
Care of Power Supply Units

**Frequent Checking Necessary**

Many modern radio receiver installations make use of a B power unit for the plate voltage, and a storage battery in conjunction with a trickle charger for the filament supply, the entire combination being controlled by means of an automatic relay. If well manufactured units are used throughout, such an installation should require practically no attention other than the addition of water to the storage battery or of trickle current to the trickle charger, if the latter is of the electrolytic type.

In order to make certain that the entire power plant is functioning satisfactorily, it is a good idea to make some simple tests every six months or so. If the rectifier tube or other part of the unit fails to function, the battery will become noticeable in the operation of the receiver. If the rectifier tube deteriorates the volume produced by the receiver will be lowered and also the quality will be impaired. A total failure of the power unit will, of course, mean that it will be impossible to hear anything at all on the receiver.

The simplest check to make on the A power unit in order to make certain that it is functioning satisfactorily is to take a hydrometer reading of the storage battery. If the battery reads "fully charged" it is possible that the trickle charging rate is excessive and it will be a good idea to somewhat reduce the rate and then make frequent tests with the hydrometer to determine how the battery is standing up. If the total charge in the battery now gradually decreases it will be best to increase the rate of trickle charge again. If, on the other hand, the battery continues to charge in a fully charged condition, we have a good indication that the previous rate of trickle charge was too high and that very probably the battery was being continually over charged, which is very harmful.

If a hydrometer reading of the battery indicates that the battery is very low the trickle charge rate should be increased so that the battery is brought up to practically full charge and then the rate should be adjusted so as to maintain the battery in this condition. The contacts in the relay controlling the installation should be inspected every so often. There is a certain amount of sparking at the contacts which tends to pit them and it might be necessary to smooth them with a piece of emery cloth.

One further check which can be made on the storage battery is to inspect it for signs of deterioration. While the battery may be in good working order, it is possible that it is still deteriorating and not showing up in the readings of the hydrometer. If this is the case the battery is probably beyond saving.

**Exponential Horns Without Vibration**

The exponential type of horn makes a very good type of loud speaker. The best horn is one which radiates the sound uniformly over the required range of frequency and it has been proved mathematically that the exponentially shaped horn conforms closely to this requirement. A horn is of the exponential type when its cross section area doubles at equal intervals along its length. For example, a horn which doubles in area every foot will reproduce down to about 64 cycles, and if it doubles twice as rapidly it will only reproduce down to 128 cycles. A properly designed horn should be free from noticeable resonance, and to prevent this the mouth of the horn should be made large enough to transmit the sound coming from it without any great amount of back pressure. In the design of loud speaker horns it has been found that, if the mouth is made comparable to 1/2 of the wavelength corresponding to the low frequency cut-off point of the horn, the resonance in the horn will be negligible.

The wavelength in feet is determined by dividing the velocity of sound in feet per second, which is 1100, by the frequency. For example, a horn whose cut-off frequency is to be 55 cycles, corresponding to a wavelength of 59 feet, should have a mouth of 59 divided by 4, or 14 feet. These facts indicate definitely that a horn, to be a good one, must be large. Small horns, whether they are or are not exponential, do not reach the low frequencies.

The horn makes it possible for a comparatively small diaphragm to get a good grip on the air and thereby produce a large volume of sound. The small diaphragm will not be affected by the large horn which may be replaced by a large diaphragm, as is done in a cone type loud speaker.

The material of which the horn is made is important. Although a horn may be well designed, and constructed to the correct size, total length and expansion per unit length it may still fail to give really good results because of resonant effects in the material used in the construction. The material used should have no marked resonant frequency unless it is very low, where it might help to increase the low note radiation.

**Closely Coupled Circuits**

It is evident from the resonant curve that the combination of these two circuits produces a resultant characteristic curve which is quite broad and flat on the top in comparison with the quite sharp peak of either circuit alone. This double peaked effect is characteristic of closely coupled circuits and has been used to some extent in radio receivers.

An ordinary resonance circuit consisting of a single coil and condenser has a comparatively sharp resonant current curve and therefore frequencies slightly above or below the resonant frequency are not amplified as well as the latter and, therefore, the tuned circuit tends to cut down the amplification of the side bands of the incoming wave which causes some loss of high frequencies. If a receiver is made up, however, with two tuned circuits, such as we have indicated, this cutting of the side bands will not take place because the points of the resonance curve can be made sufficiently broad so as to give equal amplification over a band 10,000 cycles wide and therefore precise reproduction can be obtained at all frequencies 5000 cycles above or below the carrier frequency. The circuit has not been used in actual practice to any great extent because of the careful adjustments necessary.

No. 134

**Radio Broadside Laboratory Information Sheet**

**Loud Speaker Horns**

**The Exponential Type**

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**No. 135**

**Radio Broadside Laboratory Information Sheet**

**Closely Coupled Circuits**

If two circuits are coupled together by a condenser, as shown in the sketch, and they are both adjusted so that they are tuned to slightly different frequencies, we will find that a resonance curve of the combination has the form shown by the solid curve. The resonance curve of one of the separate alone would have the form indicated by the dotted curve. It is evident from the resonant curve that the combination of these two circuits produces a resultant characteristic curve which is quite broad and flat on the top in comparison with the quite sharp peak of either circuit alone. This double peaked effect is characteristic of closely coupled circuits and has been used to some extent in radio receivers.
No. 136

Radio Broadcast Laboratory Information Sheet

**Carrier Telephony**

**Theory and Uses**

The use of power lines for the dissemination of intelligence is becoming increasingly common throughout the country. Large power companies have in many cases installed radio equipment for inter-communication between various power plants; these radio-frequency signals are then transmitted over the power lines rather than through the air, and, in this way interference is encountered. The system has also been used in some communities in order to make it possible to receive musical programs at home by connecting suitable devices directly to the power system.

For commercial use, this system has certain advantages, such as lack of interference, which make its use valuable, but it is unlikely that the system will ever replace broadcasting. The number of different stations that can be tuned-in by a subscriber using the system is naturally limited, and this is a definite disadvantage.

The system actually offers only a very little from that of ordinary broadcasting, the major difference being that the power of the transmitter, instead of being radiated into the air by means of an antenna, is coupled directly to the power line. The coupling between the transmitter and the power line is generally made as high-velocity as possible. The coupling of power line is generally made at the receiving end, using condensers and special filter and protective circuits. At the receiver end, the coupling of the radio receiver can be used to reject the signals. It also means, of course, that the coupling is a way to the transmission line. The system is generally operated in pairs as both sending or receiving can be accomplished at any of the various terminals of the system.

In carrier telephony it has generally been found that it is easier to use carrier frequencies somewhat above 50,000 cycles. For comparatively low radio frequencies, around 10,000 cycles, there is considerable loss in the various power transformers in the line, and at frequencies intermediate between about 10,000 and 50,000 cycles there will very likely be sharp resonance peaks causing excessive loss at particular frequencies. Above 50,000 cycles an ordinary transmission line is fairly satisfactory as a transmitting medium.

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No. 137

Radio Broadcast Laboratory Information Sheet

**Operating Vacuum Tubes in Parallel**

**Methods and Results**

It is sometimes desirable to operate several tubes in parallel in order to obtain a greater power output, and it is of interest to know how efficiently this may be done.

If two tubes are to be used in parallel in the output of an audio amplifier, the two sockets are wired so that the grid of one tube connects to the grid of the other and the plate of the two plate connect together. The two filaments are also connected together. The result is that with these two tubes we will have only four leads—one from the grid, another from the plates, and two others from the filaments.

The amplification constant of the combination will be equal to the product of the amplification of a single tube, provided both of the tubes have the same constant. If one of the tubes had a lower amplification constant and the other a higher constant the resultant amplification constant of the two would be equal to the arithmetic mean. If the amplification constant of one tube is five and the other four, the resultant amplification constant will be five.

The resultant plate impedance will be equal to half the impedance of a single tube. If unlike tubes are used, the total impedance can be calculated by the simple laws governing resistances in parallel. The combined impedance can be stated as follows:

\[
\text{Impedance of one tube} - \text{Impedance of other tube} \]

The greatest power output is obtained when the two tubes have identical plate impedances and amplification constants. Unfortunately, however, a very large fraction of the total power of the two tubes will be dissipated even if they differ considerably.

To illustrate, two tubes might be connected in parallel, the amplification constants of which are in a ratio of 2 to 1 and the plate impedances of which are equal, and from the combination we could obtain 90 per cent of the maximum possible power. It is evident, therefore, that the total power will not be decreased by any great amount even if tubes quite widely differing in characteristics are used. From two perfectly matched tubes, feeding into a load of equal value equal to their combined plate impedance, we can obtain twice as much power as can be obtained from a single tube feeding into a load resistance equal to its plate impedance.

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No. 138

Radio Broadcast Laboratory Information Sheet

**The Unit of Capacity**

**Calculation and Formulas**

The capacity of a condenser is stated in terms of the quantity of electricity it will hold per volt. When a condenser stores a specific quantity of electricity known as a coulomb and there is an electrical pressure of one volt across its terminals then the capacity of the condenser is one "farad." A condenser must be very large to have a capacity of a farad and therefore a millifarad is a much more practical unit, and it is called the "microfarad," meaning one-millionth of a farad. Capacities smaller than one microfarad can be used in micro-microfarads, corresponding to a millionth of a microfarad.

The capacity of a condenser may be computed from the general equation:

\[
C = \frac{Q}{V}
\]

where \( C \) = capacity of condenser in microfarads \( Q \) = quantity of electricity \( V \) = power in volts

**Example**

What is the capacity in microfarads of a condenser having 2000 plates. The dielectric consists of paraphenedlur 0.92 thick. The part of a farad and therefore a millifarad is a much more practical unit, and it is called the "microfarad," meaning one-millionth of a farad. Capacities smaller than one microfarad can be used in micro-microfarads, corresponding to a millionth of a microfarad.

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Inductive Reactance

HOW IT IS CALCULATED

If an inductance coil is connected in series with an a.c. ammeter to a source of alternating current, a certain amount of current will flow in the circuit, depending upon the size of the coil and the frequency of the current. If the voltage of the source is divided by the current, the quotient will be the "reactance" of the coil in ohms. For example, if the frequency of the current being supplied by the source of potential was 60 cycles and the voltage was 110 volts and the coil had an inductance of 1.0 henry, we would find that 0.952 amperes of current would flow through the circuit. Then 110 volts divided by 0.952 gives 116, which is the reactance in ohms at 60 cycles with the inductance of 1.0 henry. The reactance of a coil depends upon its inductance and upon the frequency of the current. It can be calculated by means of the following formula:

\[ \text{Reactance} = \frac{F}{L} \]

where \( F \) = the frequency of the current in cycles, and \( L \) = the inductance of the coil in henries.

No. 139  

\[ \text{Reactance} = \frac{F}{L} \]

per second, and \( L \) = the inductance of the coil in henries.

In many calculations it is necessary to know the reactance of some particular coil at some frequency and for this reason on Laboratory Sheet No. 140 is given a table of reactance for inductance coils between 0.01 and 100 henries at frequencies from 60 to 100,000 cycles. From the formula given herewith it is evident that the reactance of a coil is directly proportional to the inductance of the coil and also directly proportional to the frequency. Doubling the frequency will double the reactance and doubling the inductance will double the reactance. The reactance is also obtained if the frequency is doubled. If these two factors are remembered it is a simple matter to calculate mentally the reactance of any coil not given in the table on Laboratory Sheet No. 140. For example, if a 10henry coil has one third the reactance of a 30-henry coil, say, 10,000 cycles. Since the reactance of a 10-henry coil at 100 cycles is 628 ohms, it follows that the reactance of a 30-henry coil at the same frequency must be 1,884 ohms.

No. 140  

\[ \text{Reactance in ohms at various frequencies} \]

<table>
<thead>
<tr>
<th>COIL INDUCTANCE IN HENRIES</th>
<th>60</th>
<th>100</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>10,000</th>
<th>100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.001</td>
<td>3.77</td>
<td>6.28</td>
<td>15.7</td>
<td>31.4</td>
<td>62.8</td>
<td>628</td>
<td>6,280</td>
</tr>
<tr>
<td>0.005</td>
<td>18.86</td>
<td>31.4</td>
<td>78.5</td>
<td>157</td>
<td>314</td>
<td>3,140</td>
<td>31,400</td>
</tr>
<tr>
<td>0.01</td>
<td>37.7</td>
<td>62.8</td>
<td>157</td>
<td>314</td>
<td>628</td>
<td>6,280</td>
<td>62,800</td>
</tr>
<tr>
<td>0.1</td>
<td>277</td>
<td>570</td>
<td>1,340</td>
<td>2,680</td>
<td>5,360</td>
<td>53,600</td>
<td>536,000</td>
</tr>
<tr>
<td>1.0</td>
<td>874</td>
<td>1,740</td>
<td>3,570</td>
<td>7,140</td>
<td>14,280</td>
<td>1,428,000</td>
<td>14,280,000</td>
</tr>
<tr>
<td>10.0</td>
<td>3,770</td>
<td>6,280</td>
<td>15,700</td>
<td>31,400</td>
<td>62,800</td>
<td>628,000</td>
<td>6,280,000</td>
</tr>
<tr>
<td>50.0</td>
<td>11,310</td>
<td>18,840</td>
<td>47,200</td>
<td>94,400</td>
<td>188,800</td>
<td>1,888,000</td>
<td>18,880,000</td>
</tr>
<tr>
<td>100.0</td>
<td>22,600</td>
<td>36,240</td>
<td>92,600</td>
<td>185,200</td>
<td>370,400</td>
<td>3,704,000</td>
<td>37,040,000</td>
</tr>
<tr>
<td>1000.0</td>
<td>1,570</td>
<td>2,680</td>
<td>6,280</td>
<td>12,560</td>
<td>25,120</td>
<td>2,512,000</td>
<td>25,120,000</td>
</tr>
</tbody>
</table>

This table shows how the reactance of various inductance coils varies with different frequencies. Laboratory Sheet No. 139 explains what inductive reactance is and upon what it depends.

No. 141  

\[ \text{A. C. Tube Data} \]

"HEATER" AND FILAMENT TYPES

On this Laboratory Sheet are given data on the new A.C. tubes, type 227 and type 226. The heater tube is of the heater type whereas the latter is of the a.c. filament type. The heater tube requires a special five-prong socket whereas the type 25 may be used with any standard socket. The filament type is a 6-candlepower filament. It should be noted that the filament voltage of the type 25 is 110 volts and the filament current of the type 24 is .5 amperes. The filament of these tubes is quite large, especially so in a multi-tube receiver, and for this reason it is essential in wiring the filament leads that heavy wire be used. Determine the total current required by all the tubes and table No. 1 below will tell you what size of wire to use.

<table>
<thead>
<tr>
<th>TYPE OF TUBE</th>
<th>PLATE VOLTAGE</th>
<th>NEGATIVE GRID VOLTAGE</th>
<th>PLATE CURRENT</th>
<th>PLATE IMPEDANCE</th>
<th>MUTUAL CONDUCTANCE</th>
<th>UNDISTORTED POWER OUTPUT IN WATTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>227</td>
<td>90</td>
<td>5</td>
<td>3</td>
<td>11,300</td>
<td>725</td>
<td>0.020</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>7.5</td>
<td>6</td>
<td>9,400</td>
<td>870</td>
<td>0.140</td>
</tr>
<tr>
<td>226</td>
<td>90</td>
<td>6</td>
<td>3.7</td>
<td>9,400</td>
<td>875</td>
<td>0.020</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>9</td>
<td>6</td>
<td>7,400</td>
<td>1,100</td>
<td>0.070</td>
</tr>
</tbody>
</table>

Table No. 2 on this sheet gives the characteristics of these tubes under various conditions of plate and grid voltage.

CETRON AC TUBES

Cetron AC tubes are designed for long life and quiet operation. Life tests on hundreds of Cetron heater type tubes have shown a life of 5000 hours or longer without burnout. Years of experience in design engineering and development by Cetron engineers makes this possible.

Cetron AC tubes have been made experimentally for three years. During this time of development all impractical processes and materials have been eliminated and only those used that have stood the test of time.

The Cetron AC line of tubes include the following types:

- CETRON C-27, a heater type detector and general purpose tube.
- CETRON C-26, a filament type ampliﬁer tube.
- CETRON C-80, a filament type rectiﬁer tube.
- CETRON C-80H, a heater type rectiﬁer tube of superior life and power.
- CETRON C-271, a heater type power tube of long life and high output.
- CETRON C-71A, a filament type power tube.
- CETRON C-88, a special type rectifier tube for power units. This tube will deliver 800 volts from a 110 volt AC line without the use of a stepup transformer. The advantages of this are numerous. No transformer is required for "B" supply units. The condensers are worked at 110 volts instead of the usual 250 or 300 volts. This makes for longer life on the condensers with a less expensive condenser. The size of the unit is much smaller. Less condenser is needed to filter the output of the tube. This is the ideal tube for the experimenter or Power Unit manufacturer.
No. 142

Radio Broadcast Laboratory Information Sheet

Obtaining Various Voltages from a B-Power Unit

VALUES AND CURRENT-CARRYING CAPACITY

It is comparatively simple to calculate the resistance values required in the output circuit of a B-power unit in order to obtain any specific voltages. This Laboratory Sheet will explain how to calculate the values of these resistances.

Consider the fundamental output circuit of a B-power unit as illustrated in the sketch. The diagram of the rectifier and filter has been omitted since they play no important part in the calculation of resistance values. Suppose tap No. 1 is to be 45 volts and a 0.014 mfd. eliminator is used. We will assume that the loss current through R1 is 3 milliamperes, or 0.003 amperes. This is an average figure for the loss current and can generally be used in this type of calculation. If the voltage at tap No. 1 is 45, then the voltage drop across resistance R1 must be 45. The resistance of R1 will be equal to the voltage across it divided by the current through it, or, in this case, 45 divided by 0.003, which gives 15,000 ohms as the value of R1. The voltage at tap No. 2 is to be 90. Since the voltage drop across R1 is 45, it follows that the voltage drop across R2 will also be 45 in order to make the total voltage between the negative B and tap No. 2 equal to 90. The current flowing through the resistance R2 will be equal to the loss current at 3 milliamperes plus the current drawn by the detector circuit, which is 1 millampere. Therefore the value of resistance R2 will be equal to the voltage across R2 divided by the current through it, which is 0.003 plus 0.001, or a total of 0.004 amperes. This gives a value of 11,250 ohms for R2. Suppose that

No. 143

Radio Broadcast Laboratory Information Sheet

Solenoid Coil Data

UNITS FOR THE BROADCAST BAND

This Laboratory Sheet gives the data necessary to wind the secondaries of solenoid type coils for use with 0.0005-mfd., 0.0005-mfd., or 0.0005-mfd. variable condensers. The wavelength range of the coil will be approximately 200 to 850 meters. The coils may be wound on hard rubber or bakelite tubing, or some type of self-supported winding may be used.

<table>
<thead>
<tr>
<th>Number of Turns of D.C. Wire Required with Various Sizes of Tuning Condensers</th>
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<th>0.0005 mfd.</th>
<th>0.00025 mfd.</th>
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No. 144

Radio Broadcast Laboratory Information Sheet

The Transmission Unit

CORRECTION OF LABORATORY SHEET NO. 114

Two errors occurred in Laboratory Sheet No. 114 published in the August, 1927, Radio Broadcast. In the last line in the first column, the word "natural" should be changed to read "common," and in the first line in the second column, the same change should be made.

The chart on this page makes it possible to determine easily the number of telephone transmission units in the ratio of two numbers. If the transmission ratio is known, for example, from the curve it is evident that if two voltages or two currents in a ratio of 2, then the ratio difference between them is 11. If we are dealing with power rather than currents or voltages, it is merely necessary to divide the number of TU obtained from the curve by 2 in order to determine the TU difference of any two powers. For example, the powers in the ratio of 8 to 1 have a TU difference of 9. To determine this value we look up the number of TU corresponding to a ratio of 8 which gives 18 and then divide by 2.

To illustrate the use of the curve we might take an audio amplifier requiring a tenth of a volt input to produce three volts at the output. If we wished to know the overall gain in TU we would divide three by 0.1, which gives 30. This ratio on the curve corresponds to a 22.5 TU voltage gain.
No. 145

Radio Broadcast Laboratory Information Sheet

Loud Speakers

GENERAL CONSIDERATIONS

IT HAS been realized for some time that a large diaphragm type of loud speaker is capable of giving somewhat better frequency response than can be obtained from a short horn. These large diaphragm loud speakers, although they have been called gratuita because the large diaphragm in most cases takes the form of a right circular cylinder, are essentially characteristics which must be striven for in designing a loud speaker of this type, that we desire in the diaphragm is to obtain a large surface of great stiffness or rigidity and, at the same time, extreme lightness. If such material can be obtained, a very satisfactory loud speaker could be made consisting simply of a sheet of the material freely supported at the edge. Such a material having a high ratio of stiffness divided by mass is difficult to obtain, and it has been necessary to devise diaphragm shapes which will give the necessary stiffness and which will still be light. This is the reason why a cone shape has generally been used, for it will give the necessary characteristics.

Recently there was described in Radio Broadcast the Balsa wood loud speaker, which represents an attempt to obtain a large flat diaphragm using a light material, with the required stiffness obtained through the use of static radiating from the center. Because of the extreme lightness of Balsa wood it is possible to obtain in this way a very high ratio of stiffness to mass. It is, of course, essential that any loud speaker, if it is to radiate sound effectively, be made as light as possible so as to require only a small amount of energy to move it. It is desirable that the entire diaphragm shall move and that the major resistance it encounters in moving should be that due to the energy required to move the air about the diaphragm and set up sound waves in the air. Any of the available energy that is used for other purposes represents a loss.

An excellent book, Wireless Loud Speakers, is published in England by Illiffe and Sons and written by N. W. McLachlan. The author says, in speaking of cone type loud speakers: "There is a wide field for mathematical and experimental work regarding the behavior of diaphragms of various shapes and sizes, and by exact measurement, coupled with analysis, it will be possible to pave the way to better reproduction and to evolve a diaphragm with qualities superior to those now used. Until this is done we must remain in ignorance of the action of diaphragms at various frequencies. The human ear may judge one diaphragm to be better than another, but it cannot give exact data."

No. 146

Radio Broadcast Laboratory Information Sheet

B Power Device Characteristics

TYPICAL CURVES

ON THIS Laboratory Sheet are given a group of curves, supplied by the Raytheon Manufacturing Company, which show how the output voltage of a typical B power unit varies with the transformer voltage. The circuit diagram of the rectifier and filter system used in making these tests is given on the curve. The curve applies when 400 volts are used as the direct voltage of the system at no load having approximately the same value as the transformer voltages. These curves indicate the following facts:

(a) That the slope of all of the curves is the same. This is to be expected because the slope is determined entirely by the resistance of the circuit, which does not vary.

(b) That an increase of 50 volts in the transformer voltage is effective in producing an average of 75 volts increase in the output voltage.

(c) That the output voltages of the system at no load have approximately the same value as the transformer voltages.

(d) That the total resistance of the rectifier-filter system is about 1360 ohms. This value is determined by dividing the difference of any two voltages on the chart by the difference of any two current values.

It has been determined by test that the resistance of the choke coils used was known to be 600 ohms so that the effective resistance of the rectifier is about 740 ohms.

No. 147

Radio Broadcast Laboratory Information Sheet

"Gain"

and dividing by e we get:

\[ E = \frac{\text{Volts}}{R} \]

But, as stated previously, the ratio of E to e is the gain of the circuit. Therefore:

\[ \text{Gain} = \frac{E}{e} \]  \hspace{1cm} (4)

This final expression indicates that, to obtain greatest efficiency from a tuned circuit, it is essential that the ratio of the inductive reactance (X_L) to the resistance of the coil should be made as large as possible.

Why Variable Resistance Means Fixed Voltage

There are many variables or uncertain factors in any radio circuit—the type of transformer, the difference between the tubes of the same type, and even the age of the tubes; the various components that intercepted signal strength, and so on. Fixed voltages are impossible in the face of so many variables. It is absolutely essential to compensate for these unknown factors—and variable resistance is the answer.

—and Why the CLAROSTAT

But the variable resistance must be reliable. It must stay put. It must be reliable. It must handle the necessary current. It must be micro- electrically variable to meet precise requirements. All of which spells CLAROSTAT.

Duplex CLAROSTAT

Here is micro resistive resistance in multiple form—two CLAROSTATS in one. Screwdriver adjustment to provide two separate resistances of the precise values determined by actual test. Ideal for B-power voltage divider, grid bias, plate voltage control, mid-tap resistance, and so on.

Standard CLAROSTAT

A micrometric resistance of universal range—practically 0 to 5,000,000 ohms in several turns of knop, 70-watt ratings. Holds any adjustment. Noiseless. Fool-proof. Troubleproof. A time-saving device for securing adjustable voltage taps in B-power units and end-power receivers and power packs.

Power CLAROSTAT

A giant variable resistor taking the place of crude wire-wound resisters of the fixed and convenience—wire-wound values. Provides the distinct advantages usually associated with wire-wound resisters, with the additional advantage of infinite instantaneously adjust- able to meet exact requirements. Made in three resistance ranges to meet filament control, line control, and plate voltage control requirements. Holds any setting. Noiseless. 40-watt rating. Ideal for motor control in television reception.

There's a CLAROSTAT for Every Purpose—

Whether your set is home-built, custom-made, or factory product; old or new; good, bad, or indifferent, it can be improved by the proper application of one or more CLAROSTATS. And The Gateway to Superiority, described on page 68, tells how to do it. Ask your dealer about it, or write direct to:

CLAROSTAT MFG. CO., Inc.
Specialists in Variable Resistors
285-7 North Sixth St. Brooklyn, N.Y.
ABOUT

AUDIO AMPLIFIERS
POWER AMPLIFIERS

THEN READ

John F. Rider's

"A Laboratory Treatise on Audio Amplification"

a treatise unparalleled in the radio field. . . . An absolute requisite for the person building or designing audio amplifiers.

Everything you wish to know about audio frequency amplification is in this treatise. Resistance—impedance and transformer audio amplifiers and amplification are discussed in the "mil" degree. The book contains theoretical and practical data of unsurpassed detail.

Every phase of audio amplification from the design of the coupling to the energy transfer between the tube and the coupling unit is discussed. . . . Learn how to get the most volume and best quality from your audio amplifiers. . . . EVERYTHING—ABSOLUTELY EVERYTHING about audio amplifiers is contained in this laboratory treatise. . . . It is sold with a money back guarantee. . . . If you are not satisfied, your money is refunded.

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120 pages 8½" x 11" profusely illustrated. . . . Vital information on every page. . . . Information you cannot obtain in textbooks. . . . Price $2.00, postage 25c extra.

RADIO TREATISE CO.
270 Madison Avenue
New York City
No. 151

RADIO BROADCAST Laboratory Information Sheet

Single-Control

BOOSTING SENSITIVITY

ON LABORATORY Sheet No. 33, October, 1926, some facts were given regarding the transformer tuning of several condensers, to decrease the number of controls. It was pointed out that, to obtain single control, it is necessary to overcome the effect of the antenna circuit in some manner, and that a common method of doing this is as indicated in sketch A on this Sheet. The owner of a receiver of the type may greatly increase its sensitivity by connecting a varistor between the antenna and ground posts as indicated in sketch B. This, of course, adds one more control to the set but in many cases where greater sensitivity is necessary, the additional control is justified.

The increase in sensitivity that results when the varistor is used in the antenna circuit is due to the fact that it brings the antenna into resonance with the signals being received and the resultant gain in amplification is practically equal to that which would be obtained from an additional stage of radio-frequency amplification.

In some cases when the varistor is used, it will be found that the receiver tends to oscillate, or actually does oscillate, when all of the circuits are brought into resonance. Fortunately, however, non-single control receivers have a volume control in the radio-frequency system and it will be found that, by cutting down the volume control, this will be reached where the set will stop oscillating and usually the actual volume obtained with the antenna circuit tuned will be much greater than that obtained before with the volume control turned to the "maximum" position. The tendency of the circuit to oscillate can also be lessened by somewhat decreasing the r.f. plate voltage.

1st R.F. 2nd R.F.

(A)

(B)

No. 152

RADIO BROADCAST Laboratory Information Sheet

Speech


Journal of the American Institute of Electrical Engineers

Jones: "The Nature of Language." April, 1924.


Maxfield and Harrison: "Method of High-Quality Recording and Reproducing of Music and Speech Based on Telephone Research." March, 1926.

Books


No. 153

RADIO BROADCAST Laboratory Information Sheet

Standard- and Constant-Frequency Stations

The Radio Service Bulletin, published monthly by the Radio Division of the Department of Commerce, Washington, District of Columbia, contains a list of standard and constant frequency broadcasting stations as determined by the Bureau of Standards. This bureau makes measurements on an average of about three times a month on the transmitters of a small number of stations and as a result of these tests data are published in the Bulletin on those stations which have been found to maintain a sufficiently constant frequency to be useful as standards. These are known as "Standard Frequency Stations." The list of "standard frequency stations" is supplemented with a list of "constant frequency stations." No regular tests are made on these latter stations but each station in the list employs a special device, such as a crystal, to maintain its frequency accurately so that they can be generally relied upon to maintain their correct frequency.

Standard Frequency Stations

<table>
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Constant Frequency Stations

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<tr>
<td>KFVS</td>
<td>1300</td>
</tr>
</tbody>
</table>

YOU NEED ONE

If Your Line Voltage is Unsteady

An Acme VR-2 automatic voltage regulator will keep your quality good, your volume constant, and save your money by protecting the A.C. tubes in your set from dangerous voltage surges.

Many of the troubles with A.C. operated radio sets are caused by unsteady or fluctuating line voltages. Sets do not give proper volume or good quality; tubes burn out due to excessive line voltage. A five percent overload is claimed to decrease the life of an A.C. tube sixty percent. Fading, due to changes in line voltage, is experienced and in some cases howling or squealing is caused by too low line voltage.

If you have any of the troubles mentioned above, get an Acme VR-2 automatic voltage regulator. There are no tubes, liquids, or moving parts to give out. It delivers 110 volts to your set constantly even though the line may vary between 90 to 130 volts.

We are receiving letters daily telling us of the wonderful improvements the VR-2 has made in A.C. operated sets. Give your set a fair chance to produce its best. Besides, with tubes at two fifty and five dollars each, the purchase of an Acme VR2 is a money saving proposition.

Buy an Acme VR-2 automatic voltage regulator today and get results.

List Price .................. CA $20.00

Acme Apparatus Corporation
37 Osborn St.
Cambridge, Massachusetts

ACME APPARATUS CORPORATION
37 Osborn Street Dept. RB
Cambridge, Massachusetts

Gentlemen—I am interested in your VR-2 Voltage Regulator. Please send me the following information:

☐ Address of nearest Acme dealer.

☐ Bulletin No. 100 describing VR-2 in detail.
VITROHM 507-109

LONG LIFE and more selection operation
from A.C. TUBES

It takes but a moment to install the Vitrohm 507-109 Unit on your set. When it is there, you are certain of longer tube life and better reception from any a.c. tube circuit. The whole cost of this protection is only $2.00.

This Vitrohm Unit automatically reduces excessive line voltages to a safe value for the a.c. tube filaments. It has no moving parts, no manual adjustments, does not get dangerously hot, and, once installed, may be forgotten.

The Vitrohm 507-109 Unit consists of a special Vitrohm (vitreous enameled) Resistor mounted in a sturdy, perforated metal case. It is equipped with a receptacle and plug.

Full protection from line voltages to 135 is given by this unit for all a.c. sets drawing 0.4 to 0.6 amperes primary current.

Write for free information on this and other Ward Leonard Radio Products. Also see our advertisements on pages 72 and 73 of this book.

WARD LEONARD MOUNT VERNON ELECTRIC CO. NEW YORK

A.C. TUBE INSURANCE

No. 154

Resistors

Determining what Size to Use

In choosing a resistance for any particular purpose it is necessary to determine the value required, the current it must carry and then from these two facts determine the wattage rating required. The chart published on this sheet will prove useful to determine:

(a) the wattage rating a resistor must have to carry a given current,
(b) the current a resistor, of given wattage rating, will carry.

The curve is plotted to cover resistors up to 10,000 ohms and wattages ratings up to 5 watts.

Example: A resistor to be supplied C-bias to a 1774 tube. The plate current of the tube (which must flow through the resistor) is 20 milliamperes. The required C-bias voltage is 40 volts. What value of resistance and what wattage rating should the resistor have?

To calculate the required value of resistance we use Ohm's law,

\[ R = \frac{V}{I} \]

\[ R = \frac{40}{0.02} = 2000 \text{ ohms} \]

No. 155

Tube Life

Effect of Excessive Line Voltage

The life obtained from a vacuum tube depends very much upon the filament voltage at which it is operated. For voltages slightly above normal, a marked increase in life is achieved. This is true of all types of vacuum tubes, a. c. or d. c., storage-battery or dry-cell-operated. In a battery-operated receiver we are able to keep the plate voltage applied to the tubes quite accurately and normal life is therefore generally obtained from the ordinary types of storage-battery or dry-cell tubes. In an a. c.-operated receiver, however, where the filament voltages are obtained directly from the power lines, the operator of the receiver has little or no control over the filament voltage applied to the a.c. tubes. Most filament transformers are designed for a line voltage of about 115 but in many communities, rural ones especially, voltages in excess of this are frequently encountered. This higher line voltage of course affects the output voltages of the filament transformer so that the tubes are subjected to a filament voltage above normal.

It is suggested that experimenters working on a.c.-operated receivers include in the circuit some device which will enable them to control the voltage applied to the filament transformer. In cases where the line voltage is found to vary considerably so that at times it is above normal and at other times normal or below normal, it will be preferable to include in the circuit a variable resistance in the primary side of the filament transformer having a value of about 25 ohms. In those cases where the line voltage is found to be above normal but constant at this value, a fixed resistance may be placed on the primary side of the filament transformer to absorb the excess voltage so that the transformer receives its rated voltage or slightly less. For it has been found that a.c. tubes will generally give satisfactory service on somewhat less than the operating voltage at which they are rated.

When remedies for excessive line voltage, such as we have suggested here, are made use of, each case must be treated more or less individually and when, as is usually the case, the line voltage is not constant, a manually controlled resistance may be essential. These facts have been encountered by some receivers and parts manufacturers. It is probable that devices for controlling line voltage may be a useful addition to home constructors who when placed in the primary side of a transformer will automatically control the voltage actually applied to the receiver, so that the tubes will always receive a rated voltage despite fluctuations in the actual line voltage.

No. 156

Wavelength-Frequency Conversion

A Table for the Broadcasting Band

On Laboratory Sheet No. 157 is given a wavelength-frequency conversion table covering the broadcasting band. Broadcasting is assigned to channels 10 kc. up on frequencies that are divisible by 10. It is simple to use the table. If we knew that some station was transmitting on 1000 kc., we can determine from the table the corresponding wavelength, in this case is approximately 300 meters. The wavelength corresponding to a given frequency can be obtained by dividing the frequency in kc. into 300,000.

A 10-ka. separation between broadcasting stations is necessary to prevent interference between two stations on adjacent channels. When a broadcasting station is transmitting it actually uses a band of frequencies (side bands) 10,000 cycles wide—5000 cycles either side of the "carrier" frequency. The carrier frequency is the frequency assigned a station by the Federal Radio Commission, but as mentioned above, in the ordinary process of modulation a frequency band 10,000 cycles wide is used.

When a station is transmitting it also radiates a frequency exactly double its carrier frequency. The additional wave is called the second harmonic, being equal in frequency to the carrier frequency multiplied by two. Careful design and operation of the transmitter will keep the second harmonic down in amplitude and this is essential if interference is to be prevented. If a station transmits on, say, 900 kc, and also radiates a strong second harmonic with a frequency of 1800 kc, it will interfere with another station transmitting on a carrier frequency of 1200 kc. Any radio station must be considered to have two ranges: first the broadcasting range, being the distance area over which the program on the station may be received satisfactorily and, secondly, the interference range, being that area over which a station causes interference due to the production of a heterodyne which is received by the carrier of another station. The first range is much smaller than the second and a station having a service area of 100 miles will have an interference range of probably about 1000 miles.
No. 157

Radio Broadcast Laboratory Information Sheet

Table for Wavelength-Frequency Conversion

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No. 158

Radio Broadcast Laboratory Information Sheet

The Three-Tube Roberts Reflex

CIRCUIT CONSTANTS

There have been many requests for further information on the Roberts 3-tube receiver illustrated in the article appearing in "Radio" and "Broadcast" on page 209. This receiver is a reflex set consisting of a stage of r.f. amplifiers, a regenerative detector, one stage of reflexed transformer-coupled audio amplifiers, followed by a conventional low audio stage. The circuit, which will be given in this issue, is based upon the one described in the article mentioned above, and which many readers have requested, is published on Laboratory Sheet No. 159. The list of parts is given below.

La, L1—R. F. transformer. L1 may consist of 45 turns of No. 21 wire wound on a 1-inch tube. L1 should contain 40 turns of No. 21 wire with a tap at each 10 turns. L1 should be wound along the filament end of L2.

La, L2—Interstage r.f. transformer. La and L2 have the same specifications as L1 and L3, with the exception that La should be wound with No. 20 or No. 28 wire and should only be tapped at the exact center instead of at every 10 turns. That end of La nearest the grid end of L2 should connect to the plate of the r.f. tube, the center tap connects to transformer T1, and the other end of L2 connects to the neutralizing condenser. La is a movable tickler coil consisting of 20 turns of No. 20 on a 1-inch tube.

T1—Any good audio transformers.

T2—Any good output transformers.

C1, C2—0.0005-mfd. variable condensers.

S—Antenna tap switch.

C3—30-mfd. filter condenser.

T1—Double-circuit interstage jack.

T2—Single-circuit jack.

V—Volume control, 20,000-ohm variable resistance.

C, C1—Neutralizing condenser, 10,000-ohm mfd.

C2—Grid condenser, 0.0005 mfd.

R1—60-ohm grid lead.

R2—10-ohm rheostat.

R3—0.0005 fixed filament control resistance.

R4—0.0001 mfd. fixed condenser.

R5—0.00025 mfd. fixed condenser.

Eleven binding posts:

Three sockets:

Hook-up wire:

For best results a power tube should be used in the last set. If a 17T1 type tube is used with 180 volts on the plate it is needed to use a 10,000-ohm grid resistor.

When the receiver has been completely assembled it should be neutralized by tuning in some station, adjusting the tickler until the detector oscillates and a whistle is heard and then varying the neutralizing condenser until the whistle changes in pitch the least amount (its loudness will change considerably) as C1 is varied.

No. 159

Radio Broadcast Laboratory Information Sheet

The Three-Tube Roberts Reflex

Fixed Voltage Dividers and Bias Resistors

VITROHM VOLTAGE DIVIDER

507-6...........................$7.50

For use in 400-500 volt circuits. Supplies approximate voltages of 45, 67, 90, 135, Max.

VITROHM VOLTAGE DIVIDER

507-9...........................$6.75

For use in 180-250 volt circuits. Supplies approximate voltages of 22, 45, 67, 90, 135, Max.

VITROHM BIAS RESISTOR

2250 ohms, 507-16................$1.25

For use in the plate return of 112A and 171A tubes for supplying the correct grid bias voltage.

VITROHM BIAS RESISTOR

375 ohms, 507-82..................$1.75

A tapped resistor for supplying low bias voltages. Used in the common plate return. Consists of 25, 50, 100, and 200 ohm steps in series.

VITROHM RESISTOR

20 ohms, 507-63..................$1.25

A center tapped resistor for use in all circuits.

Adjustable Voltage Dividers and Bias Resistors

VITROHM DUAL ADJ USTAT. . . . . . . . $8.50

A universal voltage divider described on page 72.

VITROHM BIAS ADJUSTAT

1000 ohms..........................$3.00

For use in the plate return of single and push-pull 250, push-pull 171 and push-pull 210 tubes for supplying correct grid bias voltages.

VITROHM BIAS ADJUSTAT

2000 ohms..........................$3.50

For use in the plate return of single and push-pull 112, single 171 and single 210 tubes for supplying correct grid bias voltages.

WARD LEONARD MOUNT VERNON ELECTRIC CO. NEW YORK
WARD LEONARD

The Vitrohm
Dual Adjustat

A UNIVERSAL VOLTAGE DIVIDER FOR RADIO POWER-PACK CIRCUITS

The Ward Leonard Vitrohm *Dual Adjustat is a voltage divider for use in circuits where adjustment of intermediate voltages is desirable. It consists of two fixed sections, each in series with an adjustable section. This fixed section has 16 steps of resistance which are covered by two contact arms. Adjustment is made by means of a screwdriver.

The Dual Adjustat is arranged for either back of panel or base mounting. It is, of course, wire wound and vitreous enameled — assurance of long life and satisfactory service.

*Two types of Dual Adjustats are available: One for circuits having outputs of approximately 425 volts, and another for circuits having outputs of approximately 200 volts. In both types, all common fixed and adjustable voltages are available with the standard hookup.

Write for free information on the Dual Adjustat and other Ward Leonard Radio Products. Our other advertisements on pages 71 and 73 will interest you.

WARD LEONARD MOUNT VERNON ELECTRIC CO. NEW YORK

ELECTRIC CONTROLS

No. 160

RADIO BROADCAST Laboratory Information Sheet

LINE VOLTAGE VARIATIONS

EFFECT ON TUBE LIFE

Letters from readers have been received by the Laboratory from time to time to the effect that the life of the 171 type tube used in their power unit was very short, sometimes lasting only about 100 hours. The normal life of a 171 type tube should be at least 1000 hours. The probable cause, in many cases, of such short life is excessive filament voltage.

The transformer in a power unit is designed generally to operate with a line voltage of 110 volts a.c. With this voltage across the primary the voltage across the filament terminals of the 171 type power amplifier should be 5 volts. If the voltage across the primary is less than 110 volts, then the voltage across the filament of the tube is less than 5 volts and conversely, with input voltages higher than 110 volts the voltage across the filament of the tube will be excessive, i.e., more than 5 volts.

If the filament voltage is too high, the electronic emission from the filament will decrease and decrease of the signal will result. If, on the other hand, the filament voltage is excessive, the output of the system is not audibly affected and so without audible indication of the excessive voltage, it is likely that it will go by unnoticed. It is excessive filament voltage which must be guarded against however, if a normal length of life is to be obtained from any tube.

The extent of the fluctuations in line voltage is, of course, different in different parts of the country — in large cities the voltage is generally quite constant, while in rural communities comparatively large variations in line voltage are probable. These problems, brought about by inconsistency of line voltage, are becoming more serious as the use of a.c. operated receivers becomes more popular. In such receivers, all of the tubes are operated directly from the power line and decreased tube life due to excessive filament voltage is to be carefully guarded against.

The solution of these difficulties lies in the design of a device which will automatically control the voltage actually applied to a power unit. The type 886 tube is a device of the sort, designed to insure constant input to power operated radio receivers, despite fluctuations in line voltage. Several devices to accomplish regulation by other means are also being developed by other manufacturers and will probably be available shortly.

No. 161

RADIO BROADCAST Laboratory Information Sheet

COMPARING THE 112, 171, AND 210 TYPE TUBES

THEIR RESPECTIVE OUTPUTS

ON LABORATORY SHEET No. 162 are shown three interesting curves illustrating the relation between the three most common types of power tubes, the 112, 171, and 210 types. The curves indicate the relation between the power output of the tubes and the value of the signal voltage impressed on the grid. The maximum impedances and amplification constants of the 112 and 210 type tubes are practically identical and, therefore, the curves for these two tubes coincide from zero up to the actual point corresponding to the maximum power output of the 112, which is approximately 195 milliwatts, or 1.26 volts.

If a vertical line is drawn at any point on the curve, for example, at A, the points at which this line crosses the various curves will indicate the power output obtained from the particular tube associated with the curve being examined. In this particular case, line A, drawn to the point corresponding to a signal voltage on the grid of 15 volts indicates that, with this value of signal voltage, the power output of a 210 tube with 425 volts on the plate is approximately 0.34 watts. The power output of a 171 at the same point is approximately 0.5 watts. The maximum grid voltage that can be impressed on a 112 without resultant output distortion is about 10.5 volts and, therefore, a 112 tube cannot be used if the signal input voltage is greater than this value. At B we have drawn another line corresponding to a signal on the grid of 8 volts. Here we find that the power output of a 112 is approximately 0.1 watts and the power output of a 171 is approximately 0.38 watts. It is therefore evident that at low values of signal voltage the 210 is capable of putting more power into the loud speaker than a 171. If the grid voltage, however, is in excess of 101 volts, the 112 cannot be used and the choice then lies between the 210 and the 171. The curves indicate that the 210 will give much more power output than a 171 but it should be realized that much greater plate voltages are necessary on the 210 than on the 171. With 180 volts on the plate the 112 can deliver approximately 740 milliwatts of power, but 250 volts on the plate of the 210 will only permit this tube to handle signal voltages up to 1116 watts and the maximum output power will be only 460 milliwatts. From these data the following conclusions can be arrived at:

1. For input signals or the grid of the power tubes of 112, 171, and 210 type tubes curves with different values of signal voltage on the grid of the tube. The significance of these curves is explained in detail on Laboratory Sheet No. 161.

No. 162

RADIO BROADCAST Laboratory Information Sheet

112, 171, AND 210 TUBE CURVES

These curves indicate how the power output of the 112, 171, and 210 type tubes varies with different values of signal voltage on the grid of the tube. The significance of these curves is explained in detail on Laboratory Sheet No. 161.
No. 163

TESTING RECEIVERS

USING THE MODULATED OSCILLATOR

THE accurate determination of the characteristic of a receiver requires a careful laboratory test, but it is possible to conduct comparatively simple tests of much practical value for the testing and repairing of receivers. The instrument that will enable us to make such tests is the modulated-oscillator. From a modulated oscillator we can obtain an audio-frequency tone which can be fed into the input of the audio amplifier in a radio receiver, and the functioning of the audio amplifier thus checked, or by turning on both r.f. and a.f. amplifiers we can obtain a modulated wave which can be used to test both the r.f. and a.f. circuits.

The diagram circuit of a modulated-oscillator will be found on Laboratory Sheet No. 164. The following paragraphs will explain how to use the instrument for testing receivers.

(1.) AUDIO AMPLIFIERS

Place all the tubes in and connect all the batteries to the amplifier. Do not place the detector tube in its socket. Connect the plate terminal of the detector tube socket to audio output terminal No. 1 on the modulated oscillator. Connect both the B+ detector lead on this receiver and terminal No. 2 on the modulated oscillator to B+ on the receiver. Turn on the receiver and audio circuit of the modulated oscillator and adjust attenuometer P to give an output of medium intensity from a loud speaker connected to the output of the audio amplifier. A defect in the amplifier is indicated if the output is low or distorted or both.

(2.) RADIO-FREQUENCY AMPLIFIERS

A test of the r.f. amplifier of a receiver is accomplished by first placing all the tubes in the receiver and connecting all the batteries, and then turning about two turns of insulated wire around the coil on the oscillator, connecting the other end of the wire to the antenna post on the receiver. The oscillator should be located about ten feet away from the receiver. If the r.f. and a.f. tubes in the modulated oscillator are turned on and the receiver's tuning circuits adjusted to resonance, an audio-frequency tone should be audible in the output. Since the a.f. amplifier in the receiver was tested previously, any defect in the operation of the receiver must be located in the r.f. amplifier or detector circuit.

No. 164

A MODULATED-Oscillator

R.F. Oscillator

Push-pull output

Transformer

0.0012 mfd

A.F. Oscillator

R.F. Sw.

45 Volts

A B 30 ohm Rhodat

70-Turns Wire

on 3-tube

Oscillator

Center Tap

All the constants of the apparatus used in the instrument are given on the diagram. Some information on the use of this instrument will be found on Laboratory Sheet No. 163. The frequency of the audio-frequency oscillations can be varied by using various values of capacity across the push-pull transformer.

No. 165

AUDIO AMPLIFICATION

GENERAL CONSIDERATIONS

An audio system can be considered satisfactory if it amplifies the sounds impressed on its input sufficiently to operate adequately the loud speaker and does so without distorting the signals to an extent sufficient to become apparent in the output of the loud speaker. Such performance can only be realized when the amplifier has been correctly designed and is operated properly.

The overall frequency characteristic of an amplifier is fundamentally different from the characteristic of a single stage. This is especially true of transformer- or impedance-coupled amplifiers and is probably due, in most cases, to coupling in the plate circuits. Regenerative effects are thereby introduced into the circuit, which may produce considerable changes in the frequency characteristic of the audio system. Such effects are also present, at times, in resistance-coupled amplifiers and generally cause such an amplifier to have a "motor-boating" quality.

It is often convenient to design the amplifier so that with the regenerative effect present the system has a flat characteristic or to design two units to have a flat characteristic and then arrange the circuit so carefully that regenerative effects will not be present. This necessitates feeding all the grid and plate circuits through resistors or choke coils and bypassing all the circuits with condensers.

Some recent audio transformers are designed to have a fairly sharp cut-off at about 5000 cycles to reduce the effect of various extraneous sounds, such as tube noise, high-frequency heterodyne whistles, etc., which are composed mostly of frequencies above 5000 cycles. Frequencies above this value add little to the quality of the record or music and can therefore be eliminated without introducing noticeable distortion. It is doubtful whether the majority of broadcasting stations themselves transmit notes of more than 5000 cycles in frequency.

Also many amplifiers have a tendency to oscillate at very high audio frequencies and sometimes at supersonic frequencies. If the amplifier is designed, however, to give little or no amplification to frequencies much above 5000 cycles, the tendency of the amplifier to oscillate will be nullified.

Get the Most Out of Your Tubes

Use This Table

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<th>TUBE</th>
<th>Plated Current Approximate</th>
<th>Type</th>
<th>&quot;Hot Vacuum&quot; Approximate</th>
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<td>UX-199</td>
<td>2.50</td>
<td>3.0 V</td>
<td>UX-199</td>
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There is an AMPERITE For Every Tube

AMPERITES take little space, but they control the very lifeblood of your receiver by automatically regulating the tube filaments.

...
NORDEN-HAUCK
SHIELDED
Super-10
Licensed under Hogan Pat. 1,014,002
“Highest Class Receiver in the World”

10 Tubes
Totally shielded
Long range
Super-selective
Unlimited Power
Removable R. F. Transformers for all wave lengths up to 25,000 meters
Five 222 screen grid R. F. amplifiers
200A detector
4-stage Power Audio Amplifier Push-Pull System
Meters on Panel
Electric or Battery Operated
A precision laboratory instrument. Material and workmanship conform to U. S. Navy standards

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Full size genuine Blue Prints $2.00 Postpaid.
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Norden-Hauck, Inc.
Engineers
Builders of the Highest Class Radio Apparatus in the World
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No. 166
RADIO BROADCAST Laboratory Information Sheet

Acoustics

DAMPING AND REVERBERATION

The quality of reproduction from any loudspeaker depends to a considerable extent upon the room in which it is used and upon the room's furnishings. The reason why the room and its furnishings influence the sound output of the speaker, whether it be a piano, phonograph, or a loudspeaker, is not difficult to understand, and will be explained briefly here.

In an average room the sounds from a piano, for example, are somewhat damped by the hangings, carpets, furniture, etc., so that they decrease to inaudibility quite rapidly. When the furniture, rugs, etc., are removed and the piano is permitted to stand on the bare boards, the sounds from it will be prolonged and the music will become jumbled, especially when playing forte. This effect is due to the absence of the furniture, which normally acts as a damping agent, and also due to the fact that the piano is resting directly on the floor so that the latter acts to increase the effective area of the sound board. The sounds produced by the piano when it is in direct contact with the floor will be somewhat louder than usual, indicating increased efficiency.

Under any given room conditions the rate at which a sound dies away is the same whether the listener at any given point is seated, standing, or lying down. However, the time taken for the sound to become inaudible depends upon the distance between the listener and the source of the sound. Of course, the louder the sound, the longer it will take to decrease in volume to a point where it is inaudible. In a room containing furnishings that cause considerable damping, we may, therefore, play much louder then in an unfurnished room, without causing any excessive blurring.

A room can be too completely damped, when the playing will sound "muddy." In certain amounts of damping, or interfering of succeeding chords is considered good, for it aids coloration to the music. The importance of these matters in relation to the design of the studio in broadcasting stations is evident. The correct amount of damping must be obtained to prevent deadening the music (too much damping) or to obtain difficulties due to reverberation (too little damping).

No. 167
RADIO BROADCAST Laboratory Information Sheet

Resonant Circuits

GAIN AND SELECTIVITY

The current at resonance in a tuned circuit is equal to the voltage induced in the circuit divided by the total resistance of the circuit. The actual capacity of the condenser or the inductance of the coil used in the circuit do not enter into the calculation once the induced voltage and the resistance are known. The voltage across the coil in the circuit is equal to a constant times the current in the coil, and the inductance of the coil and, therefore, the greater the inductance of the coil. Since a vacuum tube is a voltage rather than a current operated device, it might appear that best results, i.e., greatest amplification, would be obtained by making the coil very large. When we increase the inductance of a coil by adding to the number of turns, however, we also increase the resistance and the increase in resistance nullifies to some extent the advantage gained through the use of a larger coil.

The selectivity of a tuned stage in a receiver depends upon the series resistance of the circuit; with low-resistance circuits the selectivity is good, while with high-resistance circuits the selectivity is poor. The curves on the Chart indicate the effect of resistance in the tuned circuit. Curve 1 shows the characteristic of a very low-resistance tuned circuit and curve 2 a comparatively high-resistance circuit. Since practically all of the resistance in a tuned circuit is in the coil, it follows that when constructed, fancy "low-impedance" coils should be used in a radio-frequency circuit. A coil can be made so good an to cut "side-bands," however, and thereby distort the received signal head-band suppression results in the loss of the high radio frequencies in the modulated wave.

The ratio of the inductive reactance of the coil (0.283 times the frequency times the inductance of the coil) to the radio-frequency resistance of the coil at the same frequency is made much more than 250, distortion of the "side-bands" results.

No. 168
RADIO BROADCAST Laboratory Information Sheet

The Ear

ITS CHARACTERISTICS

The characteristics of the human ear have been determined and investigated by many different scientists, and some of these characteristics are given below:

(a.) There is a minimum audible intensity below which the ear cannot detect any sounds. A curve was published on Laboratory Sheet No. 109, indicating how this minimum audible intensity varied with frequency.

(b.) There is a maximum intensity of sound above which the auditory sensation is one of pain rather than sound. The intensity and its variation with frequency was also explained on Sheet No. 109.

(c.) There is a lower limit of the pitch of a sound below which the ear will not respond. This lower limit is about 20 cycles.

(d.) There is an upper limit to the pitch of a sound above which the ear will not respond. The upper limit is about 20,000 cycles.

(e.) The ear can distinguish between about 300,000 separate sensations of sound.

(f.) The ear can respond to pressure changes between the pressure required to produce a minimum audible sound and a pressure 100 million times greater. These two pressures correspond to an energy ratio of 10,000 million.

(g.) The ear can distinguish between the loudness of various sounds. At low levels of sound intensity a change of about 45 per cent, is necessary to be distinguishable. At greater intensities a change of 10 per cent in loudness is detectable by the ear.

(h.) The ear can distinguish between the pitch of various sounds. At low frequencies a change of about 0.2 per cent, can be detected; and at higher frequencies a change of about 1 per cent is necessary.

A knowledge of these characteristics is useful to the student interested in problems of sound reproduction.
A Sensational New Tube!

Sonatron 171 AC to Replace the 171 or 171A in AC Sets

List
Price

$4.50

Offered only by Sonatron

Recognizing that the X171 and X171A did not give perfect results in AC sets, especially in the matter of long life, Sonatron's engineers have perfected a tube based on the requirements of AC circuits. This tube has a special platinum oxide coated filament, and retains all the characteristics of the X171. This new tube offers far longer life, greater volume and a correspondingly improved tone quality.

A Sensational Success!

Many thousands of these tubes are already in actual use, and it is significant that there has not been a single instance in which these tubes have been returned because of dissatisfaction.

SONATRON TUBE COMPANY
16 Hudson Street 88 Eighth Avenue
New York, N. Y.  Newark, N. J.
108 W. Lake Street, Chicago, Illinois
AmerTran Power Transformer for
UX 250 Power Tubes

A husky transformer built for doing the job, not for looks. At a plate voltage of 450 and a negative grid bias of 84 volts a single UX 250 power tube takes 55 milliamperes plate current, and two of these tubes connected push-pull would take 110 milliamperes. Add to this, 30 to 50 milliamperes which may be required by other tubes in a receiver, the plate supply should be capable of delivering 160 milliamperes. When the plate voltage is 450 and the grid bias 84 volts, the maximum D. C. output of the filter circuit should be 534 volts. Two UX 281 rectifying tubes operating full wave with a plate voltage of 600 to 650 each, are required to handle this current and voltage.

AmerTran Power Transformer Type PF-250 rates at 1200-600 volts A.C. plate winding, delivers sufficient excess voltage for the maximum requirements with a winding capacity in excess of 160 milliamperes. There are two 73/4 volt center tapped filament windings, each having a capacity of 3 amperes continuously. The primary is designed for use on 50 or 60 cycle, 115 volt circuits and has taps for 100, 110, 115 and 120 volts.

AmerTran power transformers are all designed with low core density which results in minimum hum due to stray magnetic fields, minimum mechanical vibration of laminations, and low core loss. These desirable features are not possible in small, cheaply designed transformers. All AmerTran power transformers are provided with copper ground shields between the primary and all other windings.

Ask for Bulletin No. 1033 describing fully the PF-250.

Price, each—$30.00

RADIO BROADCAST'S DATA SHEETS

No. 172

A Simple Wave-meter

CONSTRUCTION AND CALIBRATION

The circuit diagram of a wave-meter is given on the opposite page. It is evident from the diagram that the coil is simply connected across the condenser. The coil should preferably be a solenoid wound on a piece of tubing so that it will be able to withstand some abuse without any sufficient alteration in its inductance, and should have sufficient number of turns to cover the frequency band it is to be used on.

The construction of the wave-meter presents no problems. The methods of calibrating it and plotting a calibration curve may, however, require some explanation. The following steps should be followed:

1. Set the wave-meter at a distance of about two feet from the coil, and adjust the magnitude of this variation may be held to comparatively low values by good design. A power supply yielding an output voltage that does not depend upon the load may be used with practically any receiver. With a knowledge that the output actually delivered to the receiver will be constant, a constant voltage output is, however, only one of the advantages accruing from the use of a regulated power supply.

The action of the tube in holding the voltage of the output is not due to a constant voltage output but to the elimination of the small ripples which may appear as a result of insufficient litteration. The grid bias voltage makes possible a reduction in the capacity, and therefore the expense, of the final filter condenser. In fact, the tube, when in operation, has many properties in common with a large fixed condenser. One of these properties is extremely ten a.c. impedance which, when combined with its instantaneous response as a voltage regulator, enables it to perform the annoying 'motor-boating' effect which generally results when an attempt is made to use one of the ordinary B power units with many forms of amplifiers.

The fact that the regulator tube keeps the output voltage constant also permits the use of condenser of a lower voltage rating than would be permissible if the tube were not used. The rating of the condenser used in an ordinary power circuit is fixed by the maximum values of voltage that the tube is designed for. The output voltage of a piece of paper with a regulator tube is limited, even at no load, to comparatively high values and the condenser must therefore have a rating sufficient to withstand the voltage. The output voltage of a piece of paper with a wave-meter is limited, even at no load, to comparatively high values, and the condenser does not come into play until the voltage on the output is above the rated voltage and, therefore, the condenser is not called upon to withstand a voltage at all.

1. Note the output of the receiver and check the plate current; then turn the dial and note the effect on the receiver. If the receiving tube is not a Class A type, use one of the ordinary B power units with many forms of amplifiers.

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2. Take the lead from the antenna and wrap one turn around the coil of the wave-meter and then run the antenna lead over to the regular antenna relay.

3. Turn on the receiver and tune in the radio stations.

No. 137

The Regulator Tube

WYTH IT IS USED

The voltage regulator tube, or glow tube, as it is sometimes called, has found rather wide use in the design of B power units, making them capable of delivering a voltage output that is practically constant over a wide range of plate current. The output of a power unit not using a glow tube will, of course, vary with load, although the magnitude of this variation may be held to comparatively low values by good design. A power supply yielding an output voltage that does not depend upon the load may be used with practically any receiver. With a knowledge that the output actually delivered to the receiver will be constant, a constant voltage output is, however, only one of the advantages accruing from the use of a regulated power supply.

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No. 174

Grid Bias

WYTH IT IS USED

There are apparently many, as indicated by letters to the Laboratory, who still feel that the major reason for using C bias on a tube is to reduce the plate current. Although negative bias on the grid of a tube does decrease the plate current, this is not really the most important reason for its use.

C bias is used primarily to reduce distortion and make the tube operate more efficiently. In an ordinary receiver, C bias is most important in the audio-frequency amplifier, and we will, therefore, discuss on this Laboratory Sheet the effect of using various values of C bias on the grid of a tube. The curves A, B, C, and D indicate the distortion of signals which results when too little or too much bias is used. Curve A represents the voltage on the grid of the tube. Curve B shows how the plate current of the tube varies if the bias on the tube is correct. It should be pointed out that the shape of this curve is as follows: as curve A, indicating that there is no distortion being created by the tube. If too little bias is used, the positive half of the input voltage wave will cause the grid to become positive, and the tube to draw a current, and the positive peaks are then cut off as indicated at C. If the bias is too great, the grid is held on the lower bend of its characteristic and this causes the negative half of the signal to be flattened out, as shown in curve D. To prevent distortion, therefore, the proper C bias must be used.

It is especially important that the bias on the last tube be correct, for this tube must handle the greatest amount of signal current and will, therefore, overheat if too much bias is used. As a matter of information the correct bias for a 112 or 171 type tube is given below:

```
<table>
<thead>
<tr>
<th>TUBE</th>
<th>PLATE VOLS</th>
<th>C BIAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>112</td>
<td>110</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td>130</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>16.2</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>27.0</td>
</tr>
<tr>
<td></td>
<td>160</td>
<td>40.5</td>
</tr>
</tbody>
</table>
```

Positive

Negative
No. 175

**Filter Choke Coils**

**Effect of Air Gap**

If the filter circuit of a B power unit is to eliminate noise and hum as efficiently as possible, it is essential that the filter choke coils have sufficient inductance under actual operating conditions. The value of the inductance of a choke coil as measured by any direct current flowing through it will differ from the value obtainable from the manufacturer's data, and all measurements on choke coils should, therefore, be made with d.c. flowing in the winding.

When direct currents flows through a filter coil it produces a field of magnetic flux which is "lines of force," in the core. This flux tends to saturate the core and increase the inductance of the choke, and, when not used, the unit will no longer function satisfactorily in eliminating the hum.

Manufacturers are always willing to supply data on the maximum amount of d.c. current their filter choke coil can handle and this value should not be exceeded in practice.

When the filter coil is constructed, the core may be clamped tightly together or a small air gap may be left. As the current capacity rating of the coil is increased, the air gap should be increased slightly, but in no instance may it be left without. The group of curves on this sheet show this effect. The conditions under which they were obtained are given below:

- A - No air gap
- B - Average air gap
- C - Air gap at one end, 0.01 inches each
- D - Air gap at both ends, 0.005 inches each

When the filter coil is constructed, the core may be clamped tightly together or a small air gap may be left. As the current capacity rating of the coil is increased, the air gap should be increased slightly, but in no instance may it be left without. The group of curves on this sheet show this effect. The conditions under which they were obtained are given below:

- A - No air gap
- B - Average air gap
- C - Air gap at one end, 0.01 inches each
- D - Air gap at both ends, 0.005 inches each

No. 176

**How the Plate Circuit Affects the Grid Circuit**

**Reverse Action**

In working with tubes, we normally consider that the plate circuit is controlled by the grid and that there is no reverse action, which is not strictly true, for the plate circuit does affect the grid circuit in the following way:

In the first place the plate acts as a grid with respect to the regular grid in the tube and large variations in plate voltage have the same effect with respect to the regular grid, as varying the grid voltage. The reverse effect is generally not appreciable as long as the grid is held negative, as it is in the case of an amplifier. The reverse effect is important in oscillator circuits, however, where the grid is not generally negative. In making an accurate analysis of the action of the tube, the plate circuit, it is necessary to consider this effect.

The second manner in which the grid is affected by the plate is through the grid plate capacity. (c) in the diagram on this sheet, we have indicated the circuit of an ordinary r.f. amplifier and at (b) is shown the equivalent circuit with the inter-electrode resistances and capacities indicated. For the grid filament resistance of the type shown, the grid to filament capacity, C., is the inter-electrode capacity between the grid and the plate, R., the plate filament resistance, C., the grid plate capacitance, and L, the load impedance. Probably the most important of the capacities shown is the grid plate capacitance, C., for it is this capacity which permits the grid circuit to be affected by what goes on in the plate circuit. In radio-frequency amplifiers it is this capacity which causes the tube to oscillate.

The diagram at (B) should give some idea of the complexity of the network represented by a tube, and the action of this network of resistances, condensers, and inductances must be understood if the action of a tube in any particular circuit is to be accurately foreseen. J. F. Miller, in Scientific Paper of the Bureau of Standards No. 351, carefully and completely determined the dependence of the input circuit of a tube upon the output circuit.

No. 177

**Characteristics of Speech**

**Articulation**

Clear speech is only possible when the person speaking uses careful articulation. Articulation is especially important in radio for if we do not understand what we have we have not repeated. In analyzing speech sounds a clear understanding of how the various sounds are produced is essential.

The human voice consists of sustained and transient noises and is composed of a series of sounds which are naturally difficult to recognize and which therefore require articulation. The sounds which are consonant sounds are those which are produced by the tongue and are grouped under the consonants, the sounds which are not consonant sounds are those which are produced by the lips and are grouped under the fricatives. The sounds which are consonant sounds are those which are produced by the tongue and are grouped under the consonants, the sounds which are not consonant sounds are those which are produced by the lips and are grouped under the fricatives.

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No. 181  RADIO BROADCAST Laboratory Information Sheet

R.F. vs. A.F. Amplification

A COMPARISON

The SIGNAL output from a radio receiver may be increased by augmenting either the audio-frequency or radio-frequency amplification or by both. In this Laboratory Sheet we give briefly the comparative merits of audio-frequency and radio-frequency amplification. In the accompanying panely table is shown the effect on the power into the load speaker of increasing the a.f. or r.f. amplification. The first column gives the increase in amplification and the second column the increase in power into the loud speaker if this extra amplification is introduced in the audio amplifier.

This table is based on the fact, first, that the power into the loud speaker is proportional to the square of the voltage on the grid of the power tube and, secondly, that the output of the detector is proportional to the square of the voltage on its grid. When the audio-frequency amplification is increased by 10, for example, the power into the loud speaker is 100 times greater. If the radio-frequency amplification is multiplied by 10, however, the output of the detector is 100 times greater and the power into the loud speaker is 10,000 times greater. It is evident from these figures, therefore, that increases in r.f. gain are much more effective in producing greater signal than increases in audio-frequency gain.

<table>
<thead>
<tr>
<th>Added Increase in Power into Loud Speaker</th>
<th>A.F.</th>
<th>R.F.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>10,000</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>6,250,000</td>
</tr>
</tbody>
</table>

No. 182  RADIO BROADCAST Laboratory Information Sheet

Filter Condensers

How to Connect Them in Series

If we desire to place a filter condenser across, for example, a 100-volt source of direct current and have available two large-capacity 500-volt condensers, it is ordinarily not possible to connect them in series across the 1000-volt leads with safety. Why this is so will be explained on this Laboratory Sheet.

At A in the diagram is shown the connection of two condensers, C1 and C2, in series across the 1000-volt source. Now, a condenser has a definite d.c. resistance. This is generally very high but, nevertheless finite, and this resistance is represented as R1 and R2 in the diagram. The resistance of the condenser is represented as C1 and C2 in the diagram. The resistance of the condenser is represented as C1 and C2 in the diagram. The voltage drop across each condenser is proportional to the resistance and the voltage drop across the two resistances will be in direct proportion to the resistances. The resistances of condensers vary widely and therefore it is extremely unlikely that we would have two condensers with the same d.c. resistance. For example, condenser C1 might have a d.c. resistance of 100 megohms while the d.c. resistance of condenser C2 might be 900 megohms. The d.c. voltage drops across the two condensers being proportional to the resistances there would then be 100 volts across C1 and 900 volts across C2. If the two condensers were both rated at 500 volts, the obvious result would be that condenser C1 would have a very short life because of the overload being placed on it. The solution for this difficulty is to connect external resistances R1 and R2 across each condenser as indicated at C with a sufficiently low value in comparison with the internal resistance of the condenser which is always very high, so that the voltage drops will be determined by the external resistances rather than by the internal resistances of the condensers. If we have two 500-volt condensers connected to a 1000-volt source, we might equalize the voltage across them by connecting two 100,000-ohm resistors in series across the source, as indicated at C. There would be 500 volts drop across each resistance and, therefore, 500 volts would be satisfactory in operation and have normal life.

No. 183  RADIO BROADCAST Laboratory Information Sheet

The Type 280 and 281 Tubes

Their Characteristics

The characteristics of the type 280 and 281 tubes are given below. These tubes are for use as rectifiers in B power units, the 280 in circuits for full-wave rectification and the 281 in half-wave circuits. Two 280 tubes may be used, if desired, to give full-wave rectification.

Type 280 FULL-WAVE Rectifier

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filament Voltage</td>
<td>5 Volts</td>
</tr>
<tr>
<td>Filament Current</td>
<td>.5 Amps</td>
</tr>
<tr>
<td>A.C. Plate Voltage (Max.)</td>
<td>.250 Amperes</td>
</tr>
<tr>
<td>D.C. Output (Max.)</td>
<td>.200 Amperes</td>
</tr>
<tr>
<td>D.C. Output Voltage (Max.)</td>
<td>650 Volts</td>
</tr>
<tr>
<td>Condenser Voltage</td>
<td>950 Volts</td>
</tr>
<tr>
<td>Condenser Current</td>
<td>225 Milliamperes</td>
</tr>
<tr>
<td>Diameter of Tube</td>
<td>2 1/2 inches</td>
</tr>
</tbody>
</table>

Type 281 HALF-WAVE Rectifier

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filament Voltage</td>
<td>7.5 Volts</td>
</tr>
<tr>
<td>Filament Current</td>
<td>1.5 Amperes</td>
</tr>
<tr>
<td>A.C. Plate Voltage (Max.)</td>
<td>.750 Amperes</td>
</tr>
</tbody>
</table>

The type 280 tube may be used in circuits designed especially for it or may be used in circuits designed for the type 213 tube. The characteristics of these two tubes are similar with the exception that the former tube is capable of somewhat greater output than the 213. If a 280 tube is used in place of a 213, the 280 will be operating at less than full load and will consequently have a very long life. These facts must be taken into consideration when deciding to use a type 280 tube in place of a type 213.

If more than about 60 milliamperes at 600 volts is necessary to operate a radio installation, it will be a good idea to use type 281 tubes in a full-wave circuit with about 650 or 700 volts d.c. on the plate of each tube. With this arrangement an output in excess of 100 milliamperes at 600 volts will be available.

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Transformer T-3900. A power supply transformer, designed to supply A, B, and C current to a single LX-250 power tube and plate current for the receiver. To be used with two UX-251 tubes in full rectification. Operates the power tube at full capacity. T-2900, list price $80.00

T-2950. A transformer similar to type T-2900, but with additional capacity, designed to handle two UX-250 tubes in push-pull. T-2950, list price $89.30.

DOUBLE CHOKE

These Thordarson double-choke units contain two 30 heavy gauge tubes in one compound field shielded case.

T-3190, designed for use with transformer T-2900, capacity of windings 160 M.A. T-3090, list price $16.00.

T-3100, designed for use with transformer T-2950, capacity of winding 300 M.A. T-3100, list price $18.00.

SPEAKER COUPLING TRANSFORMERS

Thordarson Speaker Coupling Transformers supply every coupling possibility between current types of power tubes into either high impedance or dynamic type speakers.

R-76, designed to couple a single 171 power tube into a high impedance speaker. Case same as that of R-300 Audio Transformer. R-76, list price $6.00.

T-2876, a transformer designed to couple a single 210 power tube into a high impedance speaker. Same case as R-76. T-2876, list price $6.00.

T-2901. This transformer in a case as illustrated, couples the output of a single 250 power tube into a high impedance speaker. T-2901, list price $12.00.

T-2902. This transformer is similar to T-2901, but designed to couple the output of a single UX-250 tube into a low impedance dynamic speaker. T-2902, list price $12.00.

T-2903. A push-pull output transformer for coupling the output of two 50 power tubes into a dynamic speaker. T-2903, list price $12.00.

T-2929. Designed to couple the output of a push-pull 10 stage into a dynamic speaker. T-2929, list price $10.00.

THORDARSON ELECTRIC MFG. CO.

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No. 184 RADIO BROADCAST Laboratory Information Sheet

Tuning

THE EFFECT OF DISTRIBUTED CAPACITY

A RADIO receiver to cover the broadcasting band must be able to tune-in signals from 550 kc. to 1500 kc., a ratio of 2.7 to 1 in frequency. It can be shown mathematically that, in order to obtain this range, the ratio of the maximum to minimum of the capacity across a tuning coil must be 6.6 to 1 approximately. If we use a tuning condenser with a maximum capacity of 0.0005 mfd., then the minimum capacity across the coil must theoretically be if the desired tuning range is to be obtained 0.0005 divided by 6.6, or 0.000076 mfd. An ordinary condenser may have a minimum capacity of about 0.000025 mfd. and, therefore, it appears that we should be able to cover the broadcasting band very easily. In the circuit, however, there is another capacity across the coil which has an important effect. This additional capacity is the effective input (grid-to filament) capacity of the tube, indicated a-C in the diagram, and this capacity varies with the amount of amplification the tube is producing in the circuit. This capacity, C, is in parallel with C, the tuning condenser, and its effect must therefore be added to that of C. The result is that the actual minimum capacity of the circuit is greater than that of the minimum capacity of C, and this will tend to restrict the tuning range of the receiver unless the power transformer is taken to a variable condenser with a low minimum capacity to tune the circuit, that the coil itself does not have much distributed capacity, and that long leads connecting the coil with the condenser.

No. 185 RADIO BROADCAST Laboratory Information Sheet

Tube Overloading

THE EFFECT OF INCORRECT VOLTAGES

During recent years many familiar types of radio tubes have played the rule of "Jack of all trades," and as a result have frequently been placed in service under conditions never intended or contemplated by the manufacturer.

What constitutes "overload" on a tube, resulting in shortened life? It might be imagined that the last tube in a receiver tuned-in on a strong local station, and with the volume turned up beyond the point where the music sounds clear, would fail under this classification, but this is not the case. This is a form of overloading, but one which only results in distorted music, and in general the tube is not affected at all. A severe overload permanently affecting the tube occurs, however, when the manufacturer's specifications as regards filament, plate, and grid voltages are disregarded and higher voltages are used.

One of the popular tube types affords a good illustration of this condition. The voltages recommended for type 201-A tubes are a filament voltage of 5.0 volts, and plate voltages of 90 to 135 volts, with the grid bias specified as -5.0 and -9.0 volts respectively. If the grid bias of 13.5 volts recommended for 90 volts is omitted as equivalent to adding about 35 volts to the plate voltage, the tube would be equivalent to operation of the tube at 125 volts with 45 volts bias. The overload is, of course, correspondingly more severe if the plate voltage is raised. This is clearly shown in the table below.

<table>
<thead>
<tr>
<th>PLATE</th>
<th>GRID</th>
<th>CURRENT</th>
<th>EXTENT OF OVERLOAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>-35</td>
<td>5.0</td>
<td>Normal</td>
</tr>
<tr>
<td>135</td>
<td>-50</td>
<td>5.0</td>
<td>Normal</td>
</tr>
<tr>
<td>150</td>
<td>-50</td>
<td>5.0</td>
<td>Normal</td>
</tr>
</tbody>
</table>

The 201-A type tube is capable of withstanding some overload more successfully than other types of tubes, but as a general rule it is always advisable to follow the manufacturer's ratings regarding tube voltage.

No. 186 RADIO BROADCAST Laboratory Information Sheet

The Type 250 Tube

A NEW POWER AMPLIFIER

The type 250 is the latest tube designed for use as a power amplifier to supply large amounts of output power for the operation of loud speakers. The large output obtainable from this tube prevents any possibility of overloading of the last stage of an audio amplifier.

The filament rating is 7.5 volts, 1.25 amperes. The filament used in the filament is the rugged coated ribbon form, similar to that used in the type 250 rectifier, the plate having a dull red. The filament current may be supplied from the 7.5-volt winding of a power transformer. The low operating temperature and the increased size of this type of filament results in minimum ripple voltage of "hum."

It should be noted that although the filament and plate voltages are the same as those for the type 210 tube, the plate current is 35 milliamperes at a plate voltage of 490 volts whereas under similar conditions, the plate current of the type 210 is only 18 milliamperes. For grid voltages for these two tubes, at a plate voltage of 400 volts, are respectively 130 and 140. The larger voltage being necessary on the type 250 tube. Because of the higher plate current and operation, however, this new type tube cannot always be used to replace the type 210 tube without changing the circuit.

<table>
<thead>
<tr>
<th>PLATE VOLTAGE</th>
<th>NEGATIVE GRID BIAS</th>
<th>Plate Current</th>
<th>Plate Resistance (a-c.)</th>
<th>Neutral Conductance</th>
<th>Plate Amperage Factor</th>
<th>Max. Undistorted Power Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>-7.5</td>
<td>25</td>
<td>0.12</td>
<td>60</td>
<td>0.005</td>
<td>250 Watts</td>
</tr>
<tr>
<td>45</td>
<td>-7.5</td>
<td>35</td>
<td>0.15</td>
<td>75</td>
<td>0.005</td>
<td>50 Watts</td>
</tr>
<tr>
<td>200</td>
<td>0</td>
<td>100</td>
<td>0.05</td>
<td>55</td>
<td>0.005</td>
<td>100 Watts</td>
</tr>
<tr>
<td>200</td>
<td>0</td>
<td>300</td>
<td>0.15</td>
<td>80</td>
<td>0.005</td>
<td>200 Watts</td>
</tr>
<tr>
<td>1000</td>
<td>0</td>
<td>1000</td>
<td>0.05</td>
<td>1000</td>
<td>0.005</td>
<td>1000 Watts</td>
</tr>
<tr>
<td>1000</td>
<td>0</td>
<td>300</td>
<td>0.15</td>
<td>1000</td>
<td>0.005</td>
<td>3000 Watts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RECOMMENDED</th>
<th>MAXIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 Watts</td>
<td>450 Watts</td>
</tr>
<tr>
<td>50 Watts</td>
<td>100 Watts</td>
</tr>
<tr>
<td>20 Watts</td>
<td>30 Watts</td>
</tr>
<tr>
<td>1 Watt</td>
<td>5 Watts</td>
</tr>
<tr>
<td>100 Watts</td>
<td>1000 Watts</td>
</tr>
<tr>
<td>300 Watts</td>
<td>3000 Watts</td>
</tr>
</tbody>
</table>

Large Standard UX (CA)
Grid Bias

HOW TO CALCULATE BIAS

This Laboratory Information Sheet gives some information regarding grid bias and how it depends upon the voltage of the grid battery and the manner in which the filament circuit of the tube is wired.

The bias voltage on the grid of a tube is always specified with respect to the negative end of the filament. In drawing A of the diagram on Sheet No. 187, the grid voltage is zero.

In drawing B, the filament resistance R has been placed in the negative leg of the filament, and since the drop across this resistance is 1.0 volt, the grid bias is also 1.0 volt.

In drawing C, a 44 volt battery has been introduced in the circuit so that the grid bias is now equal to the voltage of this battery plus the voltage drop across the resistance R. The bias is therefore 44 plus 1.0 or 45 volts.

A positive grid bias of +45.0 volts is obtained if the resistance R is connected in the positive leg of the filament and the grid return is connected to the +A terminal of the battery (see sketch D). If the grid return was connected to the other leg of the resistance, the grid bias would be equal to the voltage drop in the filament or +6.0 volts.

A variable grid bias from 1.0 to +5.0 volts can be obtained by means of the potentiometer P in drawing E. With the potentiometer in the extreme left-hand position, the bias is 1.0 volt (due to the voltage drop in R) and with the arm moved over to the extreme right-hand position the bias is +5.0 volts.

From the information given in this Sheet it should be possible to determine the grid bias with any circuit arrangement.

Parts Designed for use with the UX 250 Power Amplifier Tube

No. 7568 Designed for full wave rectification using two UX 281 or similar rectifier tubes to supply B and C power to receiver and power for two UX 350 tubes. Use one No. 6551 double choke in filter circuit. Approximate D.C. output from filter 521/2V 350 mils. Secondary voltag es 650-670V 170 amp. 71V 3 amp. C.T. $13.50

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D-307 contains condensers of 4-21/2 Mfd sections with a working voltage of 400 volts for use in connection with D-600...$10.00

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Radio Broadcast’s Home Study Sheets

Determining the Capacity and Inductance of a Radio Circuit

COILS and condensers are the foundation on which every radio circuit is erected. The coils possess an electrical quantity known as inductance, and each condenser has a capacity.

The most important feature of the coil is its capacity—its ability to store electric energy. When a current flows through the coil, lines of force surround it; the sum total of these lines is known as an electromagnetic field. The word magnetic is important here, for a coil will form which normally points one end of its swinging needle toward the earth’s north magnetic pole. This field can be detected, with a compass needle or any other device using the magnetic principle, but by a charged body such as a thin leaf of paper which had been ribbed on the sever of the coil. The unit of the capacity is the farad; named after Joseph Henry, a famous American experimenter. In radio circuits the unit dealt with is the microfarad, thousandths or millionths of farads. The table on this page shows how to convert farads and microfarads to milli-farads. For example, to change milliwatts to watts, multiply by 1000.

If you divide by one thousand, and so on.

It is the size of the coil and the condenser that controls the wavelength or frequency to which a circuit tunes. The designer of the world’s best radio must know within very close limits what the inductance of his coils must be. He knows how large a capacity he must have to cover a certain band of frequencies. It is always important to know the exact value of two electrical quantities, capacity and inductance. The following experiment will enable anyone to find out the capacity of a condenser, and the inductance of a coil.

APPROXIMATE TOOLS

1. A coil of wire. The dimensions of the coil used in the laboratory are given in Fig. 1.

2. A variable condenser fitted with a dial. About 000 mfd. is the best size of condenser.

3. A radio receiver, preferably with an oscillating detector; or a tube wavemeter.

PROCEDURE

1. Connect the coil and condenser across each other and bring the coil near to the receiver or that of the tube wavemeter.

2. Tune the receiver to a known station near the center of the broadcast band, or if a wavemeter is used, set its wavelength to about 300 meters.

3. Change the setting of the variable condenser across the coil whose inductance is unknown, until resonance with the receiver is indicated by a decrease in signal strength, or by a click in the oscillographic detector if used, or by a dip in the ball of the tube wavemeter, and similarly for the modulating oscillator in the unit, 1937 Radio Laboratory.

4. Record the setting on the wavemeter for the first wavelength observed and below and below the first medium wavelength setting until the whole of the condenser has been scanned, at the same time noting down the data in Fig. 1 Table 2.

5. Compute the inductance of the coil from the following formula—

\[
\text{Inductance in Microhenries} = \frac{0.25 \times 3.5 \times N^2}{d + p + b}
\]

where 
- \(d\) is the diameter of the coil in inches \(\frac{1}{10}\)
- \(p\) is the length of the winding in inches

As an example below is the manner in which the inductance of the coil illustrated in Fig. 1 is calculated.

\[
\text{Inductance} = \frac{0.25 \times 3.14 \times 6.5^2}{2 \times 3.14 \times 6.5} = \frac{230}{270} = 2.20 \mu h.
\]

6. Calculate the capacity of the condenser at each of several of the long wavelength settings from the formula

\[
\text{wavelength} = \frac{1848}{\sqrt{\text{condenser degrees}}}
\]

where 
- \(l\) is the length of the condenser in inches
- \(C\) is the capacity in microfarads

For example 354 inches of microscopical inductance tuned to 372 meters at \(5^\circ\) on the condenser dial. What is the capacity of the condenser at that point? To simplify the problem let us change the above formula to read

\[
\text{wavelength} = \frac{354 \times 10^5}{l \times C}
\]

\[
C = \frac{354 \times 10^5}{270} = 2.03 \text{ mfd.}
\]

To provide additional examples, the capacity column in the data Table 2 has been left blank.

7. Plot this data as shown in Fig. 1.

8. Make a tap at the center of the coil and repeat the above calculations and experiment.

9. Pick out some condenser setting on each of the calculations, say 60 degrees, and see how nearly the calculated capacities check.

DISCUSSION

In our experiment we have demonstrated the phenomena known as resonance: that is, a circuit composed of inductance and capacity absorbing energy. The inductance and capacity, to which \(l\) properly tuned, have calculated the inductance of a coil by means of a formula which will give us a result accurately. To measure the length of the winding it is necessary to measure the dimensions of the coil accurately; \(l\) we make no mistake in our arithmetic, and \(l\) provides the length and diameter of the winding. The formula will be, therefore, the best accurate when the length of the winding equals the diameter of the coil.

We have demonstrated that knowing the wavelength to which a coil-condenser combination tunes, and knowing the inductance, we may calculate the capacity. This is one means of calibrating a condenser, that is, determining the relation between dip degrees or divisions and microfarads of capacity. The accuracy with which we determine the capacity by this method is too poor for all practical purposes is good enough provided, we make no error in our arithmetic; \(l\) we know the wavelength accurately, \(l\) we can set the condenser dial accurately to the wavelength of the receiver or wavemeter, and \(l\) the inductance being measured are fairly large, say 200 mfd., and not too small. This latter provision is because the actual capacity across the coil is made up not only of the capacity of the condenser but of the leads connecting coil and condenser and the distributed capacity of the coil. The latter capacity is a bothersome factor in all experimenters’ calculations and experiments. It is discussed in the Signal Corps book, Principles Underlying Radio Communication, page 239-241.

The capacity of the condenser used in the laboratory, a General Radio "tin can" Type 227-E, was actually 000 mfd. at \(5^\circ\) while our calculations showed it to be 270 mfd.—an accuracy of 10 per cent. The coil as measured on a bridge had an inductance of 200 microhenries instead of 292 as calculated —an accuracy of 96.6 per cent.

TABLE 1

<table>
<thead>
<tr>
<th>Capacity (wavelength)</th>
<th>Frequency (wavelength)</th>
<th>Capacity (wavelength)</th>
<th>Frequency (wavelength)</th>
</tr>
</thead>
<tbody>
<tr>
<td>in meters</td>
<td>in kilocycles</td>
<td>in meters</td>
<td>in kilocycles</td>
</tr>
<tr>
<td>270</td>
<td>621</td>
<td>483</td>
<td>385,000</td>
</tr>
<tr>
<td>55.0</td>
<td>526</td>
<td>596</td>
<td>276,000</td>
</tr>
<tr>
<td>60.0</td>
<td>428</td>
<td>605</td>
<td>210,000</td>
</tr>
<tr>
<td>72.0</td>
<td>496</td>
<td>735</td>
<td>196,000</td>
</tr>
<tr>
<td>80.0</td>
<td>370</td>
<td>810</td>
<td>123,700</td>
</tr>
<tr>
<td>80.0</td>
<td>336</td>
<td>888</td>
<td>114,000</td>
</tr>
</tbody>
</table>

TABLE 2

<table>
<thead>
<tr>
<th>Name of unit</th>
<th>Abbreviation</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Farad</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td>Microfarad</td>
<td>Mf</td>
<td>10^6</td>
</tr>
<tr>
<td>Micromicrofarad</td>
<td>mmfd</td>
<td>10^9</td>
</tr>
<tr>
<td>Henry</td>
<td>H</td>
<td>1</td>
</tr>
<tr>
<td>Microhenry</td>
<td>MHz</td>
<td>10^-9</td>
</tr>
<tr>
<td>Microfarad</td>
<td>Mf</td>
<td>10^{-12}</td>
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</tbody>
</table>

TABLE 3

<table>
<thead>
<tr>
<th>Capacity (wavelength)</th>
<th>Frequency (wavelength)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 mfd.</td>
<td>10^6 mfd.</td>
</tr>
<tr>
<td>100 mfd.</td>
<td>10^5 mfd.</td>
</tr>
<tr>
<td>1 mfd.</td>
<td>10^4 mfd.</td>
</tr>
<tr>
<td>100 mfd.</td>
<td>10^3 mfd.</td>
</tr>
<tr>
<td>1 mfd.</td>
<td>10^2 mfd.</td>
</tr>
<tr>
<td>100 mfd.</td>
<td>10^1 mfd.</td>
</tr>
</tbody>
</table>

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S-M leadership means just one thing—better radio for less money. Ask any one of the thousands of listeners and experimenters who have used and recommended S-M into supremacy. They'll all tell you that S-M leadership means better radio at less cost. And S-M will lead again in 1928 and 1929 by giving new developments that enable made-to-order or home-built radio sets to equal in external finish the finest factory productions, parts that place the performance of such sets utterly beyond competition, and, thru knock-down kits, radio receivers that will consistently outperform all ready-made sets at anywhere near their amazingly low prices.

New S-M Offerings Now Ready

Never has there been a design which so perfectly fulfills the requirements of the setbuilder as does the new Silver-Marshall 720 Screen Grid Six—successor to the famous Shielded Grid Six of such unparalleled popularity during early 1928. The 720 Screen Grid Six is a six-tube dual control screen grid receiver using three screen grid tubes in individually copper-shielded i.f. stages and two audio stages with the marvelous new S-M transformers—a set absolutely unequalled at the price.

On a summer evening test in Chicago, 41 stations (two on West Coast) were logged, 5 of which (in N., Y., N. J., Fla., Ga., and La., respectively) were on adjacent channels (only 10 kc. apart) to locals then on the air. The 720 Kit, complete without cabinet, is priced at $72.50. Custom-built complete in cabinet as illustrated, it costs $102.00.

And at $51.00 S-M offers the 740 “Coast to Coast” Screen Grid Four—kit that is a revelation in four-tube results. Type 740 metal shielded cabinet as illustrated, it costs $92.25 additional, for either set, finished in double tone brown, it marks a new standard of style and distinction.

The Sargent-Frantz Screen Grid Seven, type 720, is the wonder set of the season, and S-M offers, exclusively, the approved kit at $120.00. It is complete with aluminum shielding cabinet and will bring in 100 stations on any average evening.

The S-M “Round the World” Short Wave sets are the trimmest, most efficient short wave sets yet, priced from $36.00 to $51.00 complete with shielding cabinet. New S-M condensers are marvels of rigidity and flexibility in Universal single and triple types. The 695 Public Address Unipac—the first really high-powered amplifier yet offered—is priced at only $160.00 wired, or $125 for the kit. It will turn out music or voice that can be heard by 10,000 to 10,000 people. Other Unipacs and Power Supplies take care of every power need.

Of course, the most startling audio development of the last two years would logically come from S-M laboratories, as it did two years ago. The new Clough audio transformers were deservedly the sensation of the June radio trade show. In open comparative tests, S-M 255 and 256 ($60 transformers) have excelled the performance of all competitive types tested, regardless of cost. The 225 and 226 transformers at $9.00 each simply leave the most skeptical marveling.

These and many other startling new S-M parts leave small wonder at S-M leadership. They prove that you can get the best radio for the least cost from S-M.

If you don’t wish to build, yet want your radio to be custom-made with all the advantages that this implies, S-M will gladly refer your inquiries to an Authorized Silver-Marshall Service station near you. If on the other hand, you build sets professionally, and are interested in learning whether there are valuable S-M Service Station franchises yet open in your territory, please write us.

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