the GENERAL RADIO Experimenter

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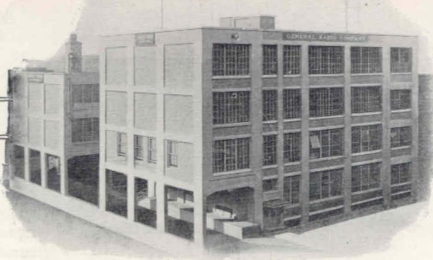


VOL. 1 NO. 7 JANUARY, 192

Design and Testing of Plate Supply Devices

By P. K. McELROY, Engineering Dept.

Part II—Testing

[*Editor's Note: The following is the second of two articles on plate supply devices, the first of which appeared in the December number of the Experimenter. Although each article is complete in itself, this second one will be clearer if it is read after reading the first article, and with a copy of the first article at hand for reference.*]

II. Testing

The first of these two articles, in last month's Experimenter, completed a discussion of the design features of power units. One of the figures used to illustrate that article is repeated for reference in this issue, as is also the diagram used in the article in that issue by Mr. Lamson on "Biasing the Power Amplifier Tube from a Plate Supply Unit." This latter diagram, Figure 3, will serve, in conjunction with Figure 2, to illustrate the circuits used in our power amplifiers, which supply, in addition to B voltages for the receiver, a power audio stage operated entirely without batteries. Reference to Figures 2a and 3 will clarify the discussion of testing methods which is to follow. The only point not covered in those two drawings is the use of buffer condensers across the supply transformer secondaries in the conventional Raytheon rectifier circuit, but it is thought that this matter is sufficiently familiar to readers to permit its omission here.

During assembly in actual production and after the Units are completed, it is essential that very comprehensive tests be applied. Naturally, the finished units must be known to be correct in all respects before being shipped out. In addition, it is found to be the best procedure to test quite completely the units at each stage of the assembly, in order to catch defects before the wax has been poured over the various parts and correction made thereby more difficult. Figure 1 at the beginning of this article shows a typical testing scene in our Plate Supply Unit Department. The man at the left is testing work in process, the man on the right finished product. A detailed explanation of each man's apparatus and test methods will shortly be given.

Figure 4 shows, side by side, two Type 400 Power Amplifier and Plate Supply Units, one complete (except for cover) and the other complete except for the wax which seals the front compartments. A little study of this cut will make clearer some of the subsequent description. The reader will also please bear in mind in the discussion to follow that the Type 400 Unit is both a Power Amplifier and a Plate Supply Unit, using a 213 rectifier and a 171 amplifier tube, and that the Type 405 is a Plate Supply Unit only, using a Raytheon BH Rectifier Tube.

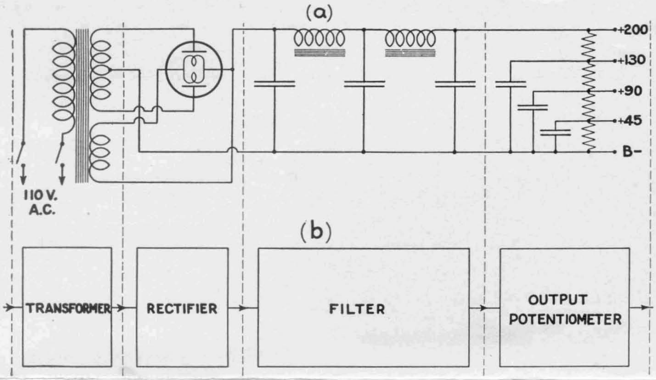


FIGURE 2

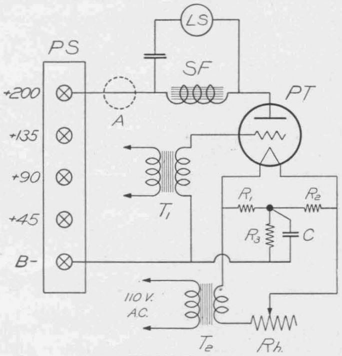


FIGURE 3

Figure 5 gives a better view of the apparatus used in testing partly completed units. It consists of

A.—Tube rectifier set for supplying high-voltage D. C. for testing condenser and transformer coil insulations.

B.—Transformer test box, containing switches for making various tests on transformers without altering connections of coil to test box.

C.—Box containing A. C. voltmeters used with transformer test box to measure high and low secondary voltages of transformers.

D.—Capacity meter, for measuring the capacity of each condenser in the unit.

E.—High-range ohmmeter for quick checking of large resistances.

F.—Low-range ohmmeter for quick checking of small resistances.

G.—Hum test board, holding circuit of 4MF condenser in series with headphones, for cutting out D.C. but listening to A. C. hum across output terminals. A short-circuiting switch is placed across the phones to protect the ears from the click due to charging current at the instant the circuit is closed.

H.—A D. C. voltmeter for measuring the output at the 45-volt tap.

J.—Two ammeters to be inserted in one side of supply line to test primary current. (Same as Item A, Figure 6, in description below).

U.—Unit under test.

This equipment is made use of for the following tests with only the two front compartments, later to be waxed, now assembled.

With 110-volt A. C. supplied to the primary of the transformer (in the small compartment) the secondary voltages are checked, and then, with no A. C. input, insulation between separate windings and between windings and case (core) is tested by high D. C. voltage. Split secondaries must have the center taps in the center, giving the same voltage for each half of the coil. On the Type 400, the biasing resistance value is checked by an ohmmeter. On the Type 405, the small buffer condensers across the high-voltage secondaries are checked by the capacity meter.

By means of the capacity meter, each condenser in the unit is checked. No insulation test is given the condensers at this point, as this is taken care of upon receipt of the condenser from the manufacturer, before the condensers are put in our stock of materials. The capacity is preferably checked not across the terminals of the condensers, but across the far ends of the wires leading from those terminals, thereby checking the wiring.

The showing of the correct resistance on the scale of the ohmmeter in checking the resistance between filter condensers both checks the wiring and shows that the chokes are not shorted or open. In a similar manner the choke of the speaker filter is tested in the Type 400.

A hot wire ammeter in series with the line, protected by a short-circuiting switch, is used to detect abnormal primary currents, caused by shorted turns in the transformer or short circuits of other kinds not

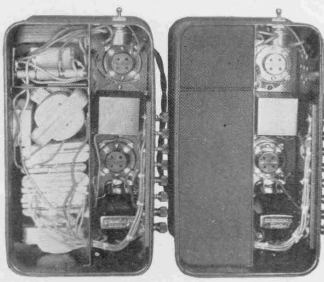


FIGURE 4

otherwise detected. This test also discloses the presence of insufficient or inferior iron in the core of the power transformer.

When these tests have been applied, the units are returned to the assemblers to have the assembly and wiring completed, after which the tubes are inserted, the unit connected to the 110-volt lines, the main switch turned off and on several

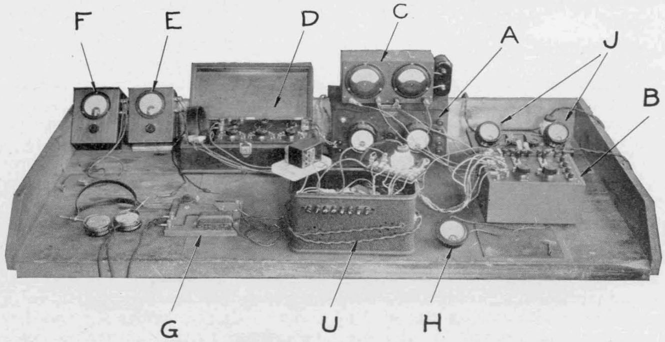


FIGURE 5

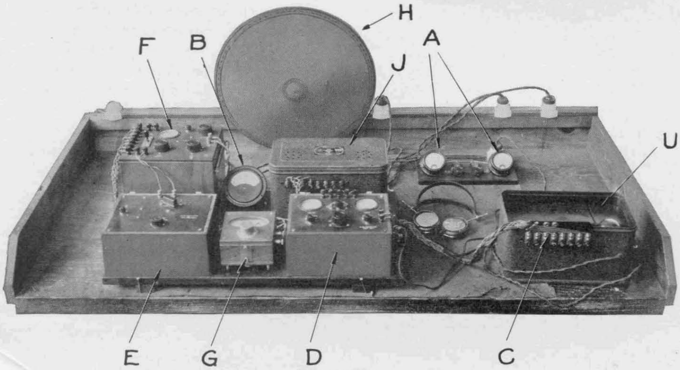


FIGURE 6

times to subject the condensers to the high momentary voltage surges encountered when the circuit is broken and the magnetic fields collapse rapidly, and these tests applied:

The voltmeter, placed across the plus 45 and B— terminal posts, should read a certain value if everything is correct. In the Type 400, the output terminals are shorted. If this lowers the voltmeter reading (except momentarily for charging current) it indicates a shorted condenser in the speaker filter.

The hum tester is placed across B— and each of the B plus voltages in turn. Abnormal amounts of hum, as learned by experience, indicate trouble. The hum tester is also applied across the speaker posts in the Type 400. While listening there, the input posts are short circuited. This should decrease the output hum considerably, since the grid is no longer floating after the transformer primary (input) has been shorted.

The value of the biasing resistance and the proper location of the center tap of the resistance unit across the amplifier filament secondary are checked by means of the ohmmeters.

A unit that has passed all of the above tests is ready to be poured with wax. After the wax has set and cooled, the unit is ready for final test using the apparatus shown in Figure 6:

A.—Series A. C. line ammeters, for showing primary current consumption. A high range meter is provided to protect the low range meter (large meter is always read first) and each is protected by a short-circuiting switch which is opened momentarily to take a reading.

B.—Line voltmeter to enable operator to decide whether voltage outputs are correct (see below, under D).

C.—Test clip, which slides quickly over binding posts and connects unit under test to remaining apparatus.

D.—Box for measuring voltage under load. A multi-point switch connects any desired B plus tap across the load resistance, a 20,000 ohm wire-wound rheostat with an off position to enable measurement of voltage at no external load. A 25 M. A. meter in series with this rheostat measures the load. A shunt extends the range to 50 M.A. when desired. The voltmeter is a 1.5 M. A. meter in series with 100,000 ohms for 150-volt range, and with 200,000 ohms for 300-volt range. In the box is also a condenser-telephone circuit, similar to that of the hum test board (Fig. 4, G) which is connected at will across the terminals where the load is applied by closing a small switch in the circuit.

E.—Audio oscillator, for testing Type 400 Power Amplifier circuit. This is a vacuum tube oscillator, the tuned circuit of which consists of an iron-core inductance and a capacity made up of several paper condensers successively cut into the circuit by a switch. The oscillator produces five frequencies, ranging from a high to a low pitch.

F.—This case contains a vacuum tube voltmeter, indications of which are read from galvanometer or microammeter G. The vacuum tube voltmeter measures the amplitude of the audio output voltage, across loud speaker H, supplied from the audio amplifier of the Type 400 (D. C. component has been removed by speaker filter incorporated in Type 400 Unit). This is compared by means of the readings of G to the output from a standard Type 400 Power Amplifier, J, which is a permanent part of this test equipment. Aural comparisons of the two Type 400's are made simultaneously by listening to the output of the loud speaker H. Either test Unit U or standard Unit J is introduced as the audio amplifier when a switch in this cabinet, F, is thrown one way or the other.

Finished Units undergo the following tests on the apparatus last described:

The primary current is checked on A, to see that it is not excessive. Each voltage tap is tested on D under three certain loads, and the voltages must come up to certain standards set by average performance of a great number of units. The switch introducing the phone circuit is closed and the hum observed on each tap under heavy load to see that it is not excessive.

For the Type 400, the load is removed, the phone circuit switch opened, and each audio frequency from E is in turn impressed first across U, then across J. For any frequency the microammeter readings will be very nearly alike for a correct Unit, although the readings from one frequency to another will vary, mainly because the oscillator delivers to the grid less energy at the low frequencies, and because of variation in the relative amounts of energy absorbed by the loud speaker at the different pitches. Listening to the loudspeaker with no input will check undue output hum. Shorting the input terminals should reduce this hum. A visual inspection follows to see that the unit is clean, that the switch Off-On plate and name plate are mounted correctly, and that the binding posts on the output panel are correct. After careful wrapping and packing in a carton, the unit is ready for shipment.

Encased parts intended for use in our Power Amplifier and Plate Supply Kits undergo similar tests which accomplish results the same as those obtained by the tests outlined above, except that, obviously, since the parts are not wired up together, no wiring external to the parts can be checked, nor can D. C. voltage output or audio output be checked.

Occasionally troubles will arise in service. Although condensers may break down, audio transformer windings open up, or other defects occur, it is quite certain that no unit leaves the factory defective or without test, since it is a rule that units do not reach the shipping room unless they have tags showing they have been tested. If, as is bound to happen, units become defective, it is fairly safe to say that such defects will have appeared only after some service.

Different defects show up differently in the behavior of the units. (See service table on next page.)

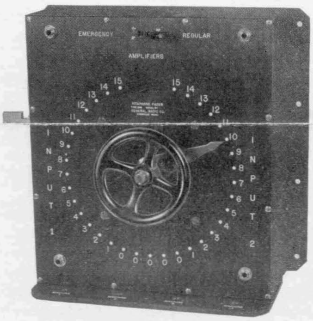
Service Table for Types 400 and 405 Units

The following table will cover most cases where failure of the Types 400 and 405 units to function properly is encountered. This table does not take completely into consideration defective tubes or conditions which lie beyond the units themselves.

EFFECT	CAUSE	
	TYPE 400	TYPE 405
NO B VOLTAGE	Open output resistance unit. Filter condenser shorted. Open filter choke. Rectifier tube defective.	Open output resistance unit. Buffer or filter condenser shorted. Open filter choke.
LOW B VOLTAGE	Speaker filter condenser shorted. Amplifier grid circuit open. Biasing condenser or resistance shorted. No bias on grid. One half of high-voltage secondary open. Defective ground from center of high-voltage secondary.	One buffer condenser shorted. One half of high-voltage secondary open. Defective ground from center of high-voltage secondary.
HIGH B VOLTAGE	Shorted filter choke. Amplifier plate circuit open (biasing resistance).	Shorted filter choke.
INCORRECT B VOLTAGES	[illegible] by-pass condenser [illegible]d. Output resistance unit shorted or open.	One mf. by-pass condenser shorted. Output resistance unit shorted or open.
OVERHEATING OF POWER TRANSFORMER	Excessive load drawn from output. Defective rectifier tube. Shorted filter condenser.	Excessive load drawn from output. Shorted filter condenser.
TOO MUCH HUM	Shorted filter choke. Open filter condenser. One side of amplifier filament center tap resistance open. Defective ground connection to common side of condensers.	Shorted filter choke. Open filter condenser. Defective ground connection to common side of condensers.
BUZZING NOISE FROM B SUPPLY (FREQUENCY VARIES WITH LOAD)		Defective Raytheon tube.
NO AUDIO OUTPUT	Defective audio transformer. Filter condenser shorted. Amplifier grid or plate circuit open. Defective amplifier tube.	
LOW DISTORTED AUDIO OUTPUT	Filter condenser shorted. Speaker filter condenser shorted. Grid circuit open on ground side of audio transformer (unilateral connection to grid). Biasing resistance shorted.	

The Vitaphone Fader

A Device Manufactured by the General Radio Co. for Use in Conjunction with Vitaphone Motion Picture Reproduction

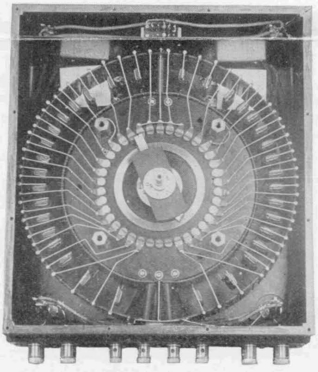


In addition to the continuous improvement of radio parts and accessories the engineering staff of the General Radio Company has frequent occasion to design and develop a wide variety of electrical instruments, both for research work and for commercial use. A recent example of their efforts along these lines is an instrument known as the Fader, which is shown in the illustrations and which forms a part of the equipment of the Vitaphone.

The Vitaphone is a new process recently perfected by the Bell Telephone Laboratories, in conjunction with the Warner Brothers Motion Picture Producers, for the electrical reproduction of speech and music as an accompaniment to motion pictures. The method may be briefly described as follows:

A large and especially fine talking machine record is made, say, of orchestration to accompany a picture. This record, which turns much more slowly than the records of the ordinary talking machine, is made large enough to play throughout a standard motion picture reel. It is placed upon a rotating table which is driven by the same motor that drives the film. Before starting, the needle is adjusted to a given index point on the record and a corresponding point is located on the beginning of the film. Hence, once started in step, a perfect synchronism between the picture and the Vitaphone is automatically maintained throughout the reel.

The needle running on the record drives a magnetophone pick-up device, consisting of an armature moving in the field of an electromagnet, whereby the vibrations which the needle receives from the record are reproduced electrically. The corresponding current impulses are then



passed into a series of power amplifiers, similar in general principle to the public address systems, where they become greatly magnified before entering a series of large loudspeaker horns concealed in the orchestra pit, and also above the screen. The reproduction is exceedingly realistic and the whole art offers wide possibilities.

The Fader consists of a series of adjustable resistances or attenuation networks, as they are called, through which the electrical currents from the magnetophone must pass before entering the amplifiers. The object of the Fader is to afford a means whereby a change from one record to another may be made in such a manner as to be quite imperceptible to the audience. It serves, likewise, as a control device whereby changes in the intensity of the reproduced sound may be made as occasion requires.

On the illustration showing the front view of the Fader will be seen the hand wheel for adjusting the attenuation networks, together with the scale for indicating the relative intensity. An interior view showing the networks mounted on the control switch is given in the other illustration.

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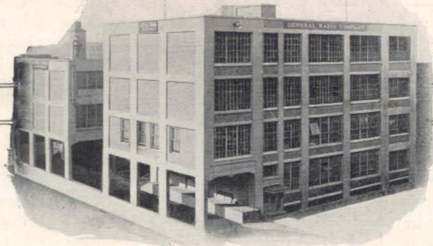
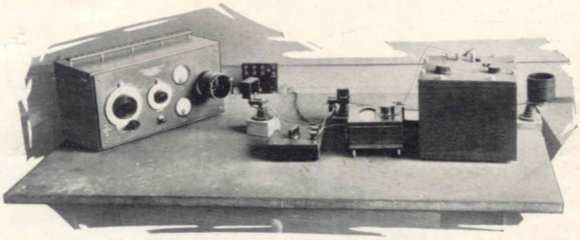


VOL. 1 NO. 8 FEBRUARY, 1927

A Study of Coil Resistances at 40 Meters

By L. B. ROOT, Engineering Dept.



When the amateur builds a short wave receiver or wave-meter, he demands the lowest loss coil that it is possible to make. There are many good coils now available, with various details of construction, but most of them fall in the classification of an "air wound" coil which is nearly self-supporting. There is no question but that this is a good type, when properly proportioned, but it has the disadvantage of being more fragile than a form wound coil and is less adaptable to that very convenient plug-in system of changing from one wave band to another. This brings the experimenter to the question of which he shall choose—lowest loss, or merely low loss, and good mechanical construction. The following measurements at 40 meters indicate some of the causes of losses in coils, and show that their source is frequently other than is supposed.

The diagram in Fig. 1 shows the method of measurement used in these tests. This is the General Radio type 353 Radio Frequency Measuring Set.

The pickup coil consists of only a few turns of wire to absorb energy from the source and feed the balance of the circuit. The coil "D" is a drop coil to by-pass the radio frequency around the high impedance of the crystal detector and galvanometer circuit, and provide a voltage drop to operate the galvanometer.

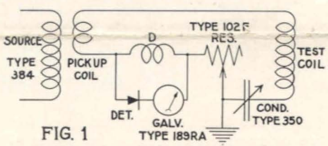


FIG. 1

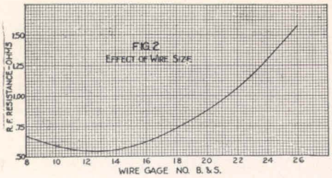
In operation the circuit is tuned to resonance with the resistance box set at zero, carefully noting the maximum galvanometer reading. Then the test coil is short-circuited and the circuit reset to resonance by increasing the capacitance of the standard condenser. The galvanometer deflection is then much greater than before, because the resistance of the test coil has been removed. Therefore, resistance is added to the circuit until the deflection at resonance is the same as before. This resistance is equal to that of the coil at the frequency of measurement.

The assumption of this method is that the resistance of the standard condenser does not change with setting. Obviously, this is not true, for it is known to decrease as the capacitance is increased. The condenser used is especially designed for this work, with the smallest possible amount of insulation, and that is placed in a weak electrostatic field. The conduction losses are very low. The circuit is sensitive enough to detect a change of 1/50 of an ohm, but when two of these condensers are connected in parallel, no change of resistance can be noted. It is, therefore, safe to neglect the resistance of the condenser, and assume that there is no change with setting.

In order to determine the proper size of wire to use for 40 meter coils, a single Type 277 moulded bakelite form was wound with various sizes of wire from No. 8 to No. 26. Each winding consisted of ten turns, and, as the length and diameter were constant, they were of essentially the same inductance. Length of coil, 1⅞"; diameter, 2¾". This was chosen as a typical coil, for it had an inductance of about 7 microhenries, and required about 50 mmf to tune to 40 meters, a very usual condition in a receiver.

Measurements of this series of coils gave the curve shown in Fig. 2.

It is evident from this curve that



there is an optimum size of wire which is not critical, but should be approached for minimum resistance. Curves taken similarly at other frequencies indicate that there is an optimum size for each wavelength band, and that the lower the frequency, the smaller the wire.

The use of collodion, shellac, or other good binders had no appreciable effect.

In order to test the effect of coil form a coil form was wound in the usual manner, and a strip of bond paper cemented to the circumference of the wire with collodion. When dry, it was possible to slip out the form without disturbing the wire. Measurements on this coil gave the following:

Resistance of coil with form .8 ohms
Resistance of coil without form .6 ohms
Gain 25%
Inductance .... 7.5 microhenries

But it is efficiency in which we are interested, and a reduction of resistance is not indicative of the true gain. It is power factor which is to be considered.

Reactance $= 2\pi fL = 6.28 \times 7.5 \times 10^6 \times 7.5 \times 10^{-6} = 353$ ohms.

$$\text{Power factor} = \frac{R}{X} = \frac{.8}{353} =$$

.23% with form.

$$\text{Power factor} = \frac{.6}{353} = .17\%$$

without form.

From this it is evident that the power factors differ by about .06%—a very doubtful gain when elimination of the form means a less rugged coil, more difficult to construct. The change of distributed capacity was too small to measure.

Some rather surprising results were obtained by placing metal in the field of the coil. The same coil was used in all the tests, having a resistance of .7 ohms, and an inductance of 7.5 microhenries. P.F. was .2%.

A strip of .010″ x 1½″ copper 4″ long was placed along the axis and inside of the coil. Power factor rose to .23%, an increase of .03%.

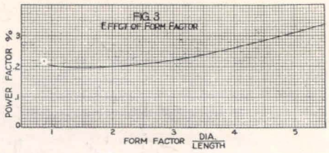
A sheet of ¼″ aluminum placed successively nearer the side of the coil had no readable effect until it actually touched the insulation, when the power factor became .21%. When placed flat against the end of the coil, the change was very slight.

A strip of .010″ x 1½″ copper was placed around the circumference of the coil, with about ½″ air space. When the loop was not closed to make a short-circuited turn, the power factor was .22%, but when closed it became .26%.

As an extreme case, a copper can was made to enclose the coil entirely, leaving about ½″ air space all around. The power factor went up to .27% in this case.

Power factor is mentioned in all of these tests rather than resistance, as a true indication of the change. In most instances, the inductance of the coil was reduced somewhat, accompanied by an increase of radio frequency resistance.

Six different coils were wound to practically the same inductance, on



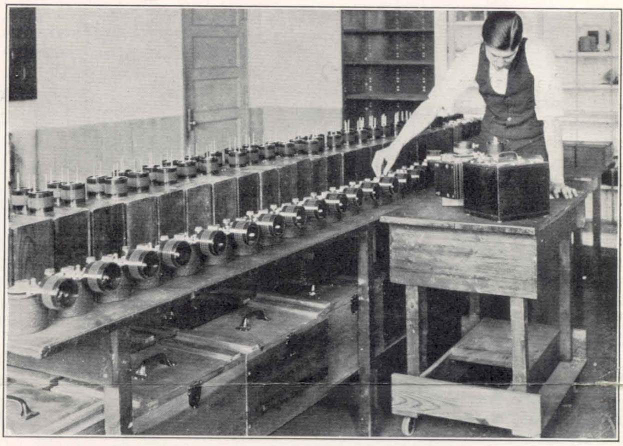
the same diameter form, but with different winding lengths, and consequently some variations in the number of turns. Inductances averaged 7 microhenries. The curve of Fig. 3 shows the results.

The object of these experiments was not to prove that bad coils are good, nor to discourage the construction of really low loss coils, but to find the causes of inefficiency, and what practical means could be taken to avoid them.

It is very evident that most of the losses come from the conductor itself, and while form and nearby metal objects do contribute, their effect is relatively small, and if

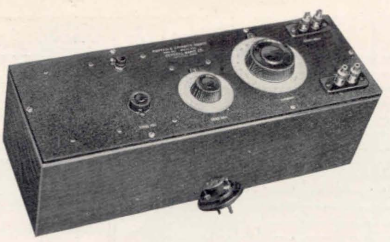
(Continued on page 3)

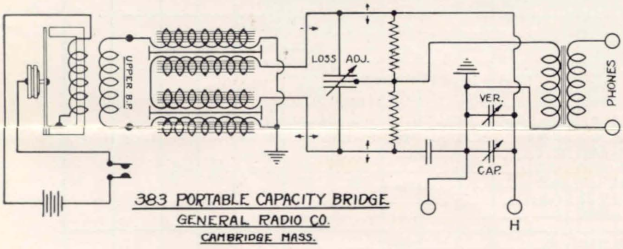
Mass Wavemeter Calibration



We are continually hearing of the use of modern efficiency methods in the production of everything from fans to flivvers. Above is illustrated an example of their application to the laboratory. Since each Type 358 Wavemeter has an individual calibration chart, the calibration of these units becomes somewhat of a problem due to large numbers manufactured as a consequence of the popularity of this wavemeter. Much time is saved by the method shown above. A number of wavemeters are set up in a long row. A radio frequency oscillator and a standard wavemeter are placed on a truck somewhat resembling a tea wagon, and the oscillator set to the proper frequency for the first calibration point, this being checked by the standard wavemeter. The table is wheeled into position so that the oscillator is coupled to the first wavemeter in line and the wavemeter condenser rotated until resonance is indicated. The dial reading for this frequency is marked down, and the truck wheeled down the line, repeating the process for each wavemeter. The oscillator is kept exactly at the proper frequency by constant reference to the standard wavemeter. The oscillator is set to another frequency, and each of the wavemeters in turn adjusted to resonance. In this manner the data for a number of calibration charts is gathered with a minimum of manipulation of apparatus. When data has been obtained in this manner for points on each coil, it is plotted and the charts mounted and boxed with the meters for shipment.

A New Capacity Bridge





The measurement of small capacities is of great importance in several branches of radio work. The inter-electrode (grid-filament, plate-filament, and grid-plate) capacities of vacuum tubes are of particular importance in the design of delicately adjusted receivers. For this reason, the measurement of these quantities is of great importance both to tube and to receiver manufacturers. The very small quantities involved (about 5 micromicrofarads) render the usual type of bridge measurement not very satisfactory for this use. Among the recently developed laboratory instruments of the General Radio Company is the Type 383 Portable Capacity Bridge, particularly designed for this type of work.

A conventional type of bridge circuit is used, consisting of two resistance and two capacity arms. It is actuated by a self-contained microphone hummer supplied from a 4½-volt dry battery. The output from the hummer, of about 800 cycles frequency, is fed through a transformer to the bridge circuit. The transformer has shielding between its primary and secondary, and is in addition wound in two sections so as to reduce capacity effects. The phones are supplied from another transformer, its primary connected across the bridge, the secondary brought to the lower terminals in the photograph. Three adjustments appear on the bridge panel, marked LOSS ADJ., ZERO ADJ., and CAPACITY. These correspond to the condensers labelled LOSS ADJ., VER., and CAP., respectively in the diagram. The LOSS ADJ. condenser, shunted across the resistance arms of the bridge, compensates for the variation from zero of the power factor of the unknown capacity. This adjustment is not calibrated as it is not intended for use as a means of measuring power factor. It is intended merely to compensate for loss current in the condenser arm which might otherwise render a balance of the bridge impossible. The zero adjust condenser is included across the balancing condenser and the unknown in order to balance out stray capacities of leads, sockets, etc. As the ratio arms and standard condenser are fixed, the total capacity in the fourth arm of the bridge, which includes the unknown with its leads, the zero adjusting and the measuring condenser must be constant for balance. In making measurements the leads, sockets, or other apparatus associated are connected to the terminals and the capacity of the ZERO ADJ. condenser reduced sufficiently to balance the bridge with the CAPACITY condenser set at maximum capacity. The dial on this condenser is set to read 180 degrees out of phase with the capacity, i.e., the dial is set at 0 for maximum capacity.

The unknown capacity is then connected and the condenser marked CAPACITY rotated (reducing its capacity) until the bridge is again balanced. The LOSS ADJ. condenser is adjusted as required in each case. The capacity of the unknown condenser is obtained by multiplying the reading of the measuring condenser by a factor appearing on the dial.

A very convenient accessory in making measurements on the inter-electrode capacities of vacuum tubes is the socket shown in the foreground. This socket is equipped with three plugs so spaced as to fit the binding posts of the bridge, and connected to grid, plate, and filament. In measuring the tube capacities, this socket is plugged in and the bridge balanced for zero. The tube is then placed in the socket and its capacities measured directly.

Readings can be made to about one-half division on a one hundred-division scale with ear-phones, or somewhat more accurately if an amplifier and vacuum tube voltmeter are used.

The new Capacity Bridge is made in two models. One, with a range extending to thirty micromicrofarads, is designed for the measurement of small capacities. Another model, its range extending to 600 micromicrofarads, is particularly useful in matching condenser units for use in single control setups. The accuracy of the instrument makes it very useful for this purpose, as it will show up smaller differences between such units than are permissible in the receiver. Its simplicity in comparison with the quartz-controlled oscillators and other expedients resorted to for condenser matching recommends it strongly.

A very useful adjunct to the capacity bridge is a two-stage amplifier. A vacuum tube voltmeter can then be used to detect balance and a somewhat greater accuracy attained than is possible with earphones. Another advantage of the voltmeter is that it permits tolerance limits to be marked on the dial of the voltmeter, a useful practice in factory inspection work.

Coil Resistance at 40 Meters

(Continued from page 2)

something else must be sacrificed, the gain may not be worth while.

Finally, it may be summed up that in designing a coil of a given inductance for the forty meter band, it is well to

1. Use about No. 12 to No. 14 wire.
2. Keep the form factor $\frac{\text{(diam.)}}{\text{(length)}}$ around 1 to 2.5.
3. Use a form if desired.
4. Use plugs and jacks if desired.
5. Use any good "dope" as a binder.
6. Use any reasonable amount of shielding where advantageous.

For all practical purposes the coil will be of low losses, mechanically strong, convenient to use, and, if wound on a good form, will retain its calibration indefinitely. And these advantages are obtained with but slight and immaterial sacrifice of efficiency.

Vacuum Tube Data Table

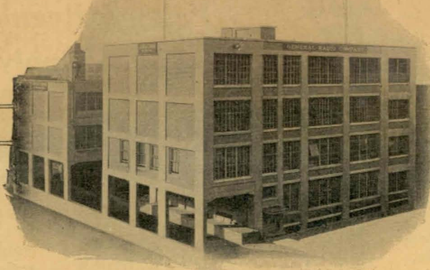
Correct to February 1, 1927

TYPE	FILAMENT VOLTS	FILAMENT AMPS.	B VOLTS	C VOLTS	PLATE CURRENT MILS	PLATE IMP. OHMS	MUT. COND. M.MHOS	AMP. FACTOR	PEAK EMISSION MILS.	OUTPUT MILLIWATTS UNDIST.	OUTPUT MILLIWATTS AS OSC.	CAPACITY COLD M.M.F.	MAX. DIA. INCHES	MAX. HEIGHT INCHES
WD 11	1.1	.25	22	0	.4	22000	260	6	25		6			
WD 12			45	-1.5	1.1	18000	345	6.2			30	G-F 6		
CX 11			67	-3	1.8	17000	365	6.2			85	G-P 5.5		
CX 12			90	-4.5	2.6	16000	390	6.2		12	150	P-F 7.5	$1\frac{7}{16}$"	$4\frac{7}{16}$"
$2.50														
UX 199	3.3	.063	22	0	4	26000	230	5.9	9		6			
CX 199			45	-1.5	1	19500	320	625			30	G-F 3.6		
UV 199			67	-3	1.7	16500	380	625			80	G-P 3.5		
CV 199			90	-4.5	2.5	15000	415	6.25		7.5	150	P-F 4.5	$1\frac{1}{16}$"	$3\frac{1}{2}$"
			135											
			90	-7.5	1.3	19000	330	625		15	80			
$2.25														
UX 120	3.3	.130	22	0	1	10000	320	3.2	24		16	G-F 4.5		
CX 120			45	4	2	8500	390	3.3			60	G-P 5.4		
			67	9	3	8000	410	3.3			140	P-F 4.4	$1\frac{3}{16}$"	$4\frac{1}{8}$"
			90	16.5	3.2	7700	430	3.3			200			
			135	22.5	7	6600	500	3.3		105	650			
			135	27	5.5	7500	430	3.2		110	500			
$2.50														
UX 201 A	5	.25	22	0	.5	26000	325	8.4	45		8	G-F 5.8		
			45	1.5	.9	18500	460	8.4			28	G-P 10.1		
			67	3	1.5	14000	600	8.4			70	P-F 6.1	$1\frac{13}{16}$"	$4\frac{11}{16}$"
			90	4.5	2	12000	710	8.5		15	130			
			135	9	2.5	11000	775	8.5		50	230			
			180	13	3	9000	940	8.5						
$2.00														
UX 112	5	.5	22	0	1.1	14500	550	8	150		17			
			45									G-F 9		
			67									G-P 11	$1\frac{13}{16}$"	$4\frac{11}{16}$"
			90	-6	2.4	8800	890	7.9		40	150	P-F 7.5		
			135	-9	6	5000	1640	8.2		120	550			
			157	-10.5	8	4800	1700	8.2		195	850			
$4.50														
UX 171	5	.5	22	0	4	3500	850	3	80		60	G-F 6.8		
			45	-5	6									
			67	-12	7						320	G-P 9.5	$1\frac{13}{16}$"	$4\frac{11}{16}$"
			90	-16.5	11	2500	1200	3		110	680	P-F 6.5		
			135	-27	16	2200	1320	2.9		350	1500			
			180	-405	20	2100	1380	2.9		700	2500			
$4.50														
UX 210	6	1.1	90	-4.5	3	9700	775	7.5	500	18	240	G-F 7		
			135	-9	5	8000	940	7.5		64	600	G-P 8		
			180	-10	7	7000	1070	7.5		145	1100	P-F 7	$2\frac{3}{16}$"	$5\frac{5}{8}$"
	7.5	1.25	250	-18	12	5600	1340	7.5		340	2700			
			350	-25	18	5100	1460	7.6		950	5500			
			425	-35	20	5000	1540	7.7		1500	7500			
$9.00														
	DWG. NO. 17				GENERAL RADIO CO. CAMBRIDGE MASS.									
UX 200A	5	.25	22		1.2	35000	570	20						
			45		1.5	30000	670	20					$1\frac{13}{16}$"	$4\frac{11}{16}$"
$4.00														
N (215 A)	1	.25										G-F 4.4 G-P 4.2 P-F 3.8	$\frac{5}{8}$"	$2\frac{1}{2}$"
			67	-6	1	20000	300	6		8	40			
V (102 D)	2	.97											$2\frac{3}{8}$"	$4\frac{1}{2}$"
			130	-1.5	.75	60000	500	30		4.2	50			
L (216 A)	5-6	1											$2\frac{3}{8}$"	$4\frac{1}{2}$"
			130	-9	8	6000	980	5.9		60	600			
E (205 D)	4.5	1.6											$2\frac{3}{8}$"	$4\frac{1}{2}$"
			350	-22.5	33	3500	2000	7		890	8000			

For those who are keeping a continuous file of the various issues of the "Experimenter" and who would like a copy of the Tube Data Table to mount on a piece of stiff cardboard for handy reference, we have extra copies which we will be glad to send on request.

The GENERAL RADIO EXPERIMENTER

VOL. 1 NO. 9 MARCH, 1927



A Discussion of Condenser Plate Shapes

By C. T. BURKE, Engineering Department

Variable air condensers are made with three general types of plate shapes, although there are many modifications of each type.

The first rotary variable condensers were made with "straight line capacity" plates. These plates were semi-circular in shape and are called straight line capacity because the curve of capacity plotted against dial divisions (angle of rotation) is a straight line. The relation between capacity, wavelength, and frequency are such that this plate shape tends to result in crowding of stations at the lower end of the capacity range. That is, there are more transmitting channels for each dial division at the lower end of the scale than the upper. This objectionable feature has led to a widespread use of other plate shapes.

The straight line capacity plates have, however, one distinct advantage when used in single-control set-ups. Where it is desired to tune several circuits with one control, some form of capacity adjustment is nearly always necessary to compensate for different zero capacitances in the several circuits. If semi-circular, (straight line capacity) units are used, this adjustment can be made by slightly advancing one or more of the units. If this be done with condensers having other plate shapes, the capacities will become unbalanced as the control dial is advanced. This is due to the fact that if the plate shape is not "straight line capacity," the capacity variation per dial division increases as the condenser is turned toward maximum capacity, and the unit which was advanced gains capacity more rapidly than the others. This feature has caused at least one important manufacturer of uni-control receivers to return to the semi-circular plate shape.

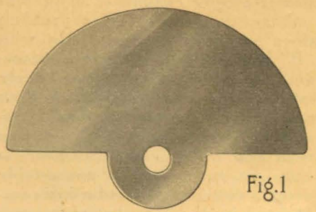


Fig.1

Straight Line Capacity

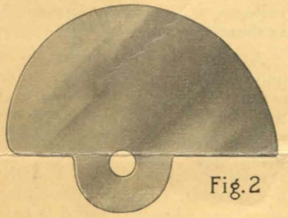


Fig.2

Straight Line Wavelength

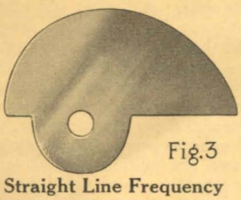
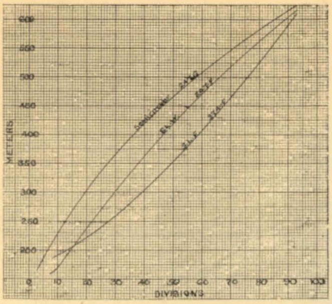


Fig.3

Straight Line Frequency

It may be noted that the effect of "straight line wavelength" and "straight line frequency" condensers is strictly a slow motion action, having a variable reduction, gradually lessening as the condenser is advanced. The same result can be and, in fact, has been accomplished by a slow motion dial so constructed as to automatically vary its reduction ratio to give the effect of a "straight line frequency" plate when used with a "straight line capacity" condenser.

The disadvantage of the semi-circular plate shape was first realized in connection with the construction of wavemeters. This was long before there were enough broadcast stations for the problem of station separation to be serious. As the relation between capacity and wave-length is not a direct proportion, a dial calibrated in wavelengths will not have equal divisions over its scale if a semi-circular plate shape is used. This not only makes the instrument more difficult to read, particularly as to the estimation of readings which fall between divisions, but involves difficulty in calibration, as the space between two points ten meters apart for instance, could not be divided into ten equal one-meter divisions. A plate shape which would give equal divisions for equal wave-lengths, i.e., "straight line wavelengths," was highly desirable, and a condenser with such a plate shape was first used commercially in the General Radio 124 wavemeter, introduced in 1916. When the multiplication of broadcast stations began, the straight line wavelength plate was introduced for condensers used in receivers, and became very popular, due to the better separation of stations resulting from its use.

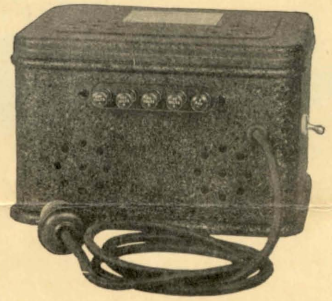


The above chart shows the calibration curves for the three distinct types of General Radio condensers, the maximum capacity of each type being 500 MMF

Broadcast stations continued to multiply, however, until all channels in the wavelength range allotted to broadcasting were filled. The transmission channels were assigned on the basis of uniform frequency rather than uniform wavelength separation, and, as they all became occupied, the difficulty of crowding a great many more than half the stations into the lower half of the dial again rose. The obvious step was, of course, the "straight line frequency plate" shaped to give equal frequency divisions over the dial. This plate shape not only improves the distribution of stations over the dial, but is the only type of condenser which can be used in a single-control superheterodyne, where there is a constant difference of frequency between the two circuits being tuned.

Certain objections, however, have prevented this type of condenser from achieving the wide popularity which was promised for it. In order to obtain a "straight line frequency" variation, an extremely low minimum capacity is required. The stray or "zero" capacity of most receivers is so large as to defeat this requirement and to prevent the realization of a true straight line frequency variation. Another objection was the large physical dimensions of most of the straight line frequency condensers, due to the fact that this plate shape is very inefficient in its use of space. Then, too, there is the fact that in the conventional type of condenser, there is a rotation of but 180° in which all stations must be included. Spreading out stations on the lower portion of the dial necessarily results in crowding them closer together on the upper. It so happened that the policy of the government in assigning channels was to give the high powered stations channels in the upper portion of the wave band, and the crowding together of these stations, generally having the better programs, proved disadvantageous.

Voltage Regulation of Plate Supply Units



One of the most bothersome problems in connection with the design of power supply equipment is that of voltage regulation. This problem does not arise in connection with "B" batteries as their internal resistance is quite low and a relatively large current may be drawn without appreciable drop in terminal voltage. The resistance of the rectifier tube and filter circuit, however, is sufficient to cause an appreciable drop in voltage. This is further complicated by the fact that resistances must be used to get intermediate voltages, which cause further drops at these terminals.

At first, variable resistances were universally resorted to in order to set the voltage at each terminal to the desired value. This arrangement proved open to several objections. In the first place, it added several controls to those already on the receiver, a distinct disadvantage at a time when the trend is toward simplification and elimination of adjustments. A further objection was that very few users of the power units had a suitable voltmeter for adjusting the voltage. A very high resistance voltmeter is required for this purpose, as the ordinary voltmeter used for checking "B" battery voltages, draws sufficient current to change the voltage of the plate supply greatly. As a result, the voltage of these instruments having adjustments was in most cases set at the wrong value. This is not so serious of itself, as present day tubes do not usually require a particularly critical adjustment of plate current.. There was a strong temptation, however, to make excessive use of the voltage control in an effort to clear up trouble having its source elsewhere. It proved, unfortunately, that many of the variable resistances offered for this work were not equal to the strain of almost continual adjustment, and trouble developed due to the noisy action of these devices.

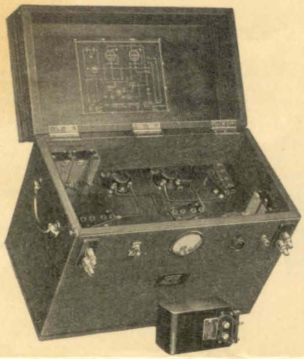
These considerations made the elimination of the variable resistance highly desirable. While this arrangement does not permit an exact adjustment of voltage, if the resistances are properly proportioned, it is possible to hold the voltage at any terminal within fairly narrow limits over the range of current likely to be drawn from it.

In a plate supply designed for this purpose, the resistance across the output circuit is relatively low, so that a considerable current is drawn from the rectifier when no tubes are connected. When tubes are connected to the plate supply, the series-parallel circuit resulting, consisting of tubes and the output resistance of the filter, is very complicated. Briefly, however, as tubes are inserted into the circuit the "bleed" current through the low tap resistance decreases, and part of it flows through the tubes. Thus the drain on the rectifier and its output voltages does not change as much as it would were the variable high resistance system used. The result is greatly improved regulation. In fact, it is possible to have a lower voltage drop per mil at the lowest tap than occurs in the overall voltage, despite the greater resistance of the circuit from which it is drawn.

A plate supply designed along this line will fit the needs of a great number of cases without adjustments of any kind. In the few cases which it does not fit, the adjustable factor may easily be added.

Another advantage of the low output resistance is that it limits the rise in voltage when the load is turned off, lessening the possibility of damage to filter condensers. This design, combined with a judicious choice of condensers, has practically eliminated the problem of condenser puncture.

The Type 415 Laboratory Amplifier



The sensitivity of a great many laboratory measurements can be increased by the use of a properly designed amplifier. An amplifier also makes possible the substitution of a visual for an auditory balance of bridge circuits operating at 800 to 1,000 cycles. This feature is of advantage, for example, in connection with the 383 capacity bridge. When this instrument is set up for factory test work, a vacuum tube voltmeter may be used as an indicator, which greatly simplifies the setting of tolerances. An amplifier is necessary also in making observation by means of an oscillograph such as the General Radio Type 338, where the circuit conditions must not be disturbed by the measuring equipment.

In the Type 415 amplifier, the necessary equipment and batteries are contained in a single cabinet of stout construction. The audio coupling units are mounted on our Type 274 plugs so that any type of coupling unit desired may be used. This feature makes possible a quick determination of the relative merits of different types of amplifying systems. The output of the second tube may be connected directly to the output terminals or by means of a plug base to any form of output coupling device desired. Four-plug plates may be obtained which may be used for mounting various types of coupling units.

The battery space is sufficient for four 22-volt "B" batteries, one 4.5-volt "C" battery and three 1.5-volt "A" cells. The amplifier is designed for use with WX-12 or UX-199 (CX-12 or CX-299) tubes. A voltmeter in the panel provides for proper adjustment of the filament voltages.

The price of the Type 415 Laboratory Amplifier, exclusive of tubes, batteries and transformers, is $40.

How Good Is "GOOD"?

How good is "good"? What are the requirements of a good amplifier?

It will be readily conceded by all that a perfect amplifier is one which will cause a reproducer to set up in a room exactly the same combination of sound waves as existed in the room where the transmitter microphone was placed. The reproduced sounds depend on a great many factors beside the amplifier, and the original sound may be changed either before it enters or after it leaves the amplifier. Before reaching the receiving audio amplifier, the sound passes through a microphone, several amplifiers, often several hundred miles of telephone line, a few or hundreds of miles of space, the radio frequency amplifier and detector. Each successive element of the system has an opportunity to alter the characteristic of the original sound, and most of them take advantage of it to a greater or less degree. The composite effect of these elements in the system includes both addition and subtraction.

In considering the amplifier, we are then confronted by the fact that the product delivered at the amplifier input terminals is no longer capable of reproducing the sound waves existing at the microphone. Even a "perfect" amplifier per se, then, can not deliver a perfect output. The amplifier cannot replace that which has been lost. Possibly, however, it can partially remove the sounds which have been added, without removing any of the original sound. Many of the noises added to the signal as it traverses the transmitting and receiving systems occur at relatively high frequencies, above 5,000 cycles. The experiments of Dr. Harvey Fletcher of the Bell Telephone Laboratories have demonstrated the fact that frequencies above 4,000 or 5,000 cycles may be eliminated from speech and music without noticeable effect. It seems then desirable that the amplifier be so designed as to cut off at about 5,000 cycles, and that such an amplifier would give more nearly perfect results than a "perfect" amplifier.

Under present conditions, the signal probably suffers more between the time it leaves the amplifier and the time it strikes the ear than it does before reaching the amplifier. That is to say, the loudspeaker is probably a greater source of frequency distortion than all the rest of the system.

The loss of the lower frequencies is due principally to the inability of many loudspeakers to reproduce frequencies much lower than 200 cycles. It does not seem to be generally realized how high this actually is, in many cases around 200 cycles. The sensitivity at low frequencies of two of the best types of present day speakers was checked at 60 cycles, by means of an oscillograph. The oscillograph was first connected to the input and the input signal adjusted for an exactly sinusoidal wave form. The oscillograph was then switched to a pickup and the sound wave in the room was seen to be of 120 cycles frequency. A stiff connection was made between the speaker and the pickup, and a 60 cycle wave appeared, showing that while the speaker was vibrating at 60 cycles, no measurable energy was being radiated at that frequency. Another test with a different type of speaker showed that the full output of a UX-210 tube was required to get an audible sound at 60 cycles.

Someone has made the suggestion that since reproducers are more or less peaked at the middle or upper frequencies, transformers should be designed to have a corresponding hollow. This is upsetting the perfect amplifier with a vengeance. It would seem more logical, however, for the loudspeaker manufacturer to equip his instrument with a filter to cut off the peaks of the curve in somewhat the same manner as telephone lines are "equalized." If the amplifier were made to match the speaker, it would be necessary to discard the entire amplifier every time an improvement was made in reproducers.

To the manufacturer of coupling units, the problem of "how good is good" presents itself in a very practical manner. How far down in the low frequency region is it reasonable to go? How much of this band, which does not now exist in the input to the amplifier, and could not be reproduced if delivered to the speaker, should the amplifier be capable of passing? It boils down to: "Is the public willing, and justifiably so, to pay more for a transformer that will amplify as low as 30 cycles than for a transformer capable of amplifying frequencies of the order of 100 cycles, when no actual gain in quality of reproduction results from the higher cost?"

Fortunately, the low frequencies that our present reproducers will not radiate are not lost. These frequencies are reproduced in the ear from their harmonics and the fundamental pitch of the note is not lost, although if the cut-off of the amplifying and reproducing systems is too high, it loses "naturalness." It is to the detector action of the ear that most of the bass notes we hear are due, and they come from no farther out the "vasty" ether than the ear of the listener.

SIZE B. & S.	DIAMETER-MILS	AREA IN CIR. MILS	TENSILE STRENGTH IN LBS. - HARD	TENSILE STRENGTH IN LBS. - SOFT	FEET PER OHM	FEET PER POUND					OHMS PER POUND 68°F					OHMS PER 1000 FT 68°F	FUSING POINT IN AIR	TURNS PER INCH						POUNDS PER 1000 FEET						COST PER POUND IN CTS.					
						BARE	SINGLE SILK	DOUBLE SILK	SINGLE COTTON	DOUBLE COTTON	BARE	SINGLE SILK	DOUBLE SILK	SINGLE COTTON	DOUBLE COTTON			BARE	ENAMEL	SINGLE SILK	DOUBLE SILK	SINGLE COTTON	DOUBLE COTTON	BARE	ENAMEL	SINGLE SILK	DOUBLE SILK	SINGLE COTTON	DOUBLE COTTON	BARE	ENAMEL	SINGLE SILK (White)	DOUBLE SILK (White)	SINGLE COTTON	DOUBLE COTTON
1	289	83700	3746	2234	8062	3.95					.0005					.126								253											
2	258	66400	3127	1772	6394	4.98					.00078					.159								201											
3	229	52600	2480	1405	5070	6.28					.00124					.201								159											
4	204	41700	1967	1114	4021	7.91					.00197					.253								126											
5	182	33100	1559	883	3180	9.98					.00314					.319								100											
6	162	26300	1237	700	2529	12.6					.00498					.403								79.5											
7	144	20800	980	555	2005	15.9					.0079					.508								63											
8	128	16500	778	440	1590	20					.0126					.641								50											
9	114	13100	617	349	1261	25.2					.02					.808								39.6											
10	102	10400	489	277	1000	31.8					.0314					1.02	333							31.4											
11	91	8230	388	219	793	40.1					.0507					1.28	284							24.9										21	22
12	81	6530	307	174	629	50.6					.0806					1.62	235							19.8										21	22
13	72	5180	244	138	499	63.8					.1284					2.04	200							15.7										22	23
14	64	4100	193	109	396	80.4					2032					2.58	166	15.6	14			14	13	12.4	1268			1268	12.92		21			23	24
15	57	3260	153	87	321	101.4					3166					3.25	139	17.5	16			15	14	9.86	10.05			10.08	10.27		22			24	26
16	51	2580	133	69	249	127.9					.515					4.09	117	19.6	18			17	16	7.82	7.97			8.01	8.18		22	38	50	25	28
17	45	2050	97	55	197	161.3					.819					5.16	99	22	21			20	18	6.20	6.32			6.37	6.51		23	39	52	27	29
18	40	1620	77	43	156.5	2034					1.302					6.51	82.8	25	23			22	20	4.92	5.01			5.08	5.19		23	39	55	28	31
19	36	1290	61	34	124	256.5					2.076					8.21	66.7	27.8	27			25	22	3.90	3.97			4.04	4.13		24	42	62	30	33
20	32	1020	48	27	98.4	323.4	319	312	311	298	3.293	3.23	3.175	3.15	3.02	10.4	58.3	31	29	27	25	27	25	3.09	3.14	3.13	3.20	3.22	3.29		25	47	67	31	36
21	28.5	810	38	21.5	78.1	407.8	398	389	389	370	5.235	5.125	5.025	4.97	4.72	13.1	49.3	35	32	30	27	30	27	2.45	2.475	2.49	2.56	2.57	2.63		27	51	73	34	39
22	25.3	642	30.2	17.1	61.91	514	504	493	491	461	8.321	8.12	7.96	7.87	7.44	16.5	41.2	39	36	34	30.5	34	30	1.94	1.970	1.98	2.03	2.05	2.11		26	52	83	34	42
23	22.6	509	24	13.6	49.09	648	645	631	624	584	13.24	12.9	12.6	12.4	11.7	20.8	34.5	44	40	38	34	37	32	1.54	1.555	1.573	1.604	1.63	1.68		27	54	89	35	47
24	20.1	404	19.1	10.8	38.92	818	795	779	778	745	21.05	204	19.9	19.6	18.2	26.2	28.9	50	45	43	38	41	35	1.22	1.232	1.241	1.298	1.30	1.34		28	61	98	38	51
25	17.9	320	15.1	8.55	30.86	1031	1004	966	958	903	3347	32.4	31.5	30.9	28.4	33	24.6	56	50	47	41	45	38	.97	.980	.991	1.04	1.04	1.08		29	67	109	42	58
26	15.9	254	12	6.8	24.47	1300	1240	1202	1188	1118	53.23	51.3	49.7	48.5	44.3	41.6	20.6	63	57	52	45	50	41	.769	.777	.791	.833	.828	.873		31	75	121	45	62
27	14.2	202	9.45	5.35	19.41	1639	1615	1542	1533	1422	84.64	81.4	78.3	76.5	68.8	52.5	17.7	70	64	58	50	55	45	.61	.616	.631	.666	.661	.703		33	81	139	50	71
28	12.6	160	7.5	4.25	15.39	2067	2023	1917	1903	1759	134.6	129	123	120	106	6.62	14.7	79	71	64	53	60	48	.484	.485	.499	.521	.524	.562		35	94	149	85	85
29	11.3	127	6	3.4	12.21	2607	2625	2485	2461	2207	214	204	194	190	164	83.4	12.5	88	81	71	58	65	51	.384	.384	.397	.416	.421	.457		37	105	167	61	93
30	10	101	4.75	2.7	9.68	3287	3325	2909	2893	2534	340.2	322	306	294	252	105	10.25	100	88	80	66	71	55	.304	.303	.315	.332	.336	.372		40	115	200	68	109
31	8.9	79.7	3.75	2.12	7.86	4145	3820	3683	3483	2768	5284	510	477	461	384	133	8.75	112	104	87	71	76	58	.241	.242	.254	.267	.271	.307		43	133	219	89	124
32	8	63.2	2.97	1.68	6.09	5227	4876	4654	4414	3737	860.3	803	747	717	585	167	7.26	125	120	95	76	84	62	.191	.192	.203	.214	.215	.248		43	149	259	94	148
33	7.1	50.1	2.36	1.33	4.83	6591	6243	5689	5638	4697	1367	1265	1165	1195	880	211	6.19	141	130	105	83	90	66	.152	.152	.161	.172	.174	.201		45	174	304	107	168
34	6.3	39.8	1.87	1.06	3.83	8311	7757	7111	6400	6168	2175	1995	1810	1715	1315	266	5.12	159	140	110	88	97	69	.120	.121	.130	.140	.141	.161		47	211	345	127	203
35	5.6	31.5	1.49	.84	3.04	10480	9660	8534	8393	6737	3458	3140	2820	2640	1960	335	4.37	179	160	130	104	104	73	.0954	.101	.110	.119	.120	.137		51	242	405	152	236
36	5	25	1.18	.67	2.41	13210	11907	10040	3846	7877	5497	4880	4340	4070	2890	423	3.62	200	190	140	110	117	82	.0757	.081	.089	.096	.099	.112		58	294	488	176	268
37	4.5	19.8	.93	.53	1.91	16660	13474	10670	11636	9309	8742	7680	6660	6180	4230	533	3.08	222	205	150	115	123	85	.060	.07	.077	.082	.084	.096		68	344	590	208	292
38	4	15.7	.74	.42	1.51	21010	16516	14220	13848	10660	13772	12100	10250	9430	6150	673	2.55	250	225	160	120	130	88	.0476	.051	.058	.065	.071	.088		83	464	746	243	353
39	3.5	12.5	.59	.33	1.2	26500	22260	16520	18286	11910	21896	18850	15600	14200	8850	848	2.2	285	255	180	130	142	90	.0377	.039	.045	.053	.058	.081		102	548	891	289	399
40	3.1	9.9	.47	.26	.95	33410	26950	21330	24381	14220	34823	29300	23650	21300	12500	1070	1.86	321	280	200	140	151	92	.0299	.031	.037	.040	.046	.072		139	693	1149	346	452

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For those who are keeping a continuous file of the various issues of the "Experimenter" and who would like a copy of the Copper Wire Table to mount on a piece of stiff cardboard

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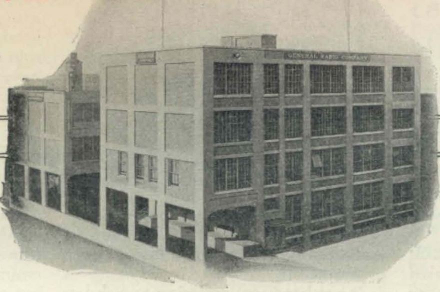


VOL. 1 NO. 10 APRIL, 1927

New Tubes for Old

By HORATIO W. LAMSON, Engineering Department

An old Arabian legend tells how Aladdin, seeking to recover his magic but unpretentious-appearing lamp which had been unwittingly discarded by a servant, went to the market place, where he astonished the populace by offering to give away new lamps for old. In a like manner a modern Aladdin might offer to give new lamps (vacuum tubes) in exchange for old without deserving much credit as a philanthropist. All of which introduces us to the subject of the reactivation of vacuum tubes by the simple process of rejuvenating their filaments.

**TYPE 388
VACUUM TUBE REACTIVATOR**

An instrument for testing and restoring thoriated vacuum tubes

A large part of the vacuum tubes used in radio reception today have the so-called thoriated filaments. Chief among these are the Radiotrons: UV and UX-199, UX-120, UX-200-A, UX-201-A, UX-171, UX-210, UX-213 and UX-216-B; the Cunningham tubes: C and CX-299, CX-120, CX-300-A, CX-301-A, CX-371, CX-310, CX-313 and CX-316-B; and corresponding tubes from other manufacturers.

The electronic emission of these tubes, that is, their plate current, depends upon the presence of a layer of thorium atoms on the outer surface of the filament. The filament is not thorium-coated, however, after the manner of the oxide-coated filaments, but is, rather, permeated throughout its whole substance with this rare element, thorium. During the normal operation of these tubes the thorium on the outer surface of the filament gradually evaporates. This would correspondingly reduce the emission current and render the tube very short-lived were it not for the fact that the thorium is continuously replenished from the interior of the filament. As long as the filament voltage in normal use is not raised over ten percent above the rated value this evaporation and replenishing continues at an equilibrium rate, so that a constant layer of thorium is maintained on the surface.

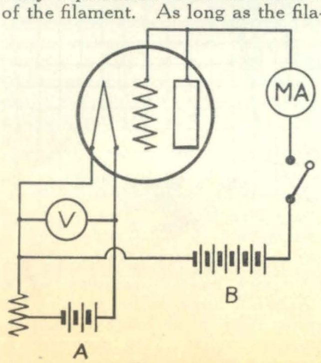


Figure 1

When subjected to an overvoltage on the filament, however, the evaporation becomes excessive so that the thorium surface layer is partially or completely diminished, and the tube accordingly more or less paralyzed. Operating these tubes at subnormal voltages is also liable to paralyze them slowly, as the filament temperature is then so low that the process of boiling out the thorium from the interior of the filament becomes abnormally retarded. Hence, it is important that the thoriated filament tubes be run at their rated filament voltages. It may be noted here that the maximum life of the "dry cell" tubes is attained when they are operated with a voltage of 3.3 across the filament.

While the great majority of thoriated tubes after a long and useful life gradually die a natural death, others are not infrequently executed by excessive voltages. In either case, if the filament is not actually burnt out, the chances are very good that the tube may be restored to life and vigor by the simple process of reactivation.

Before the cure we must diagnose the disease, and so before reactivation we should test the emission of the tube to ascertain if it is actually

Type of Tube		Fil. E. M. F.	Plate E. M. F.	Min. Emission
UV-199 C-299	UX-199 CX-299	3.3	50	6 m. a.
UX-120	CX-220	3.3	50	15 m. a.
UX-201A	CX-301A	5.0	50	25 m. a.
UX-200A	CX-300A	5.0	50	12 m. a.
UX-171	CX-371	5.0	50	50 m. a.
UX-210	CX-310	6.0	100	100 m. a.
UX-213	CX-313	4.0	100	50 per anode
UX-216B	CX-316B	6.0	125	100

below normal. To do this the circuit shown in Figure 1 is used. The grid and plate are tied directly together and then joined to the plus terminal of the B battery through a milliammeter. The negative B battery terminal is joined to the negative end of the filament and a key switch, normally open, is included in the plate circuit. The voltage across the filament, read on "V," should first be adjusted to the values specified in the table, which give also the proper values of B battery to use with the different tubes. These values should not be exceeded. Now depress the key just long enough to obtain a reading of the emission current on MA. (Disregard the change in voltmeter reading caused by the emission current.) If the emission current obtained under these conditions is zero, or any value less than the minimum specified in the table, the tube can doubtless be improved by reactivation. These values and the recommended voltages were taken from literature furnished by E. T. Cunningham, Incorporated.

Reactivation can advantageously be accomplished in two steps: the first known as "flashing" and the second as "cooking." In both of these processes the grid and plate of the tube should be **completely disconnected** from any external circuits.

For flashing three-volt tubes, a voltage of twelve is applied to the filament for a period of about one second. This will completely paralyze the tube as the surface layer of thorium is wholly evaporated, but the "boiling-out" process within the filament is expedited by the flashing to such a degree that, if the tube is now cooked with a voltage of four across the filament, the surface layer will be rapidly replaced, so that, in a few moments, the emission of the filament will come back to normal and the rejuvenated tube is ready for another long lease of life. A constant "cooking voltage" of four is permissible in this case because there is no emission current to expedite surface evaporation.

If a subsequent emission test shows that the filament failed to respond to this reactivation process it is evident that the tube has served its normal life or else has been so heavily overloaded that the vacuum has been impaired.

The five-volt tubes should be flashed for the same interval at eighteen volts on the filament and cooked at seven volts. Flashing is not recommended for the power amplifiers UX-210 or CX-310, or the rectifier tubes UX-213, CX-313, UX-216-B and CX-316-B. These tubes may, however, be reactivated merely by cooking them for longer intervals. The UX-213 or CX-313 at six volts and the others at nine volts on the filament.

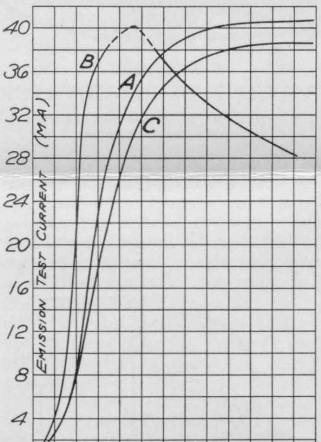


Figure 2

Curve A in Figure 2 shows the customary normal recovery of a UX-201-A tube while cooking at seven volts, after being flashed at eighteen volts. This recovery is slow at first, then increases rapidly, and finally slows down again as a saturation value is reached. When the tube was flashed at eighteen volts and then cooked at its rated filament voltage (five volts), the same saturation current was finally attained, but only after thirty-five minutes of cooking. Likewise recovery to the same saturation current, when cooked with four volts on the filament, required a period of two and one-half hours. On the other hand, cooking at nine volts on the filament caused a prompt recovery, but the saturation current was subsequently reduced, as shown in curve B, since, in this case, evaporation from the surface (even with no emission current) exceeded the boiling-out of thorium from the interior.

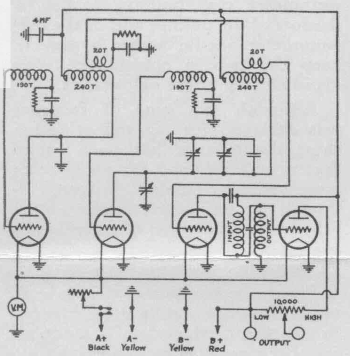
Curve C shows the recovery of the 201-A tube flashed at twelve volts and cooked at seven volts. The rate of recovery and final saturation values are seen to be slightly less than curve B, where the same tube was flashed at eighteen volts. It should be stated that the data for curve C were actually taken before the data for curve B, so that the results cannot be explained by a deterioration of the tube. Thus it is apparent that the recommended voltages for flashing and cooking should be used to secure best results.

It was found that tubes could, on the average, be flashed and recovered six or eight times before showing any decrease in the saturation current, which would indicate a deterioration of the filament. This deterioration, however, was not rapid, a dozen flashings serving to reduce the saturation current by only 8 or 10 percent. This does not mean, however, that the total life of a thoriated filament properly used may be increased tenfold by reactivation. Reactivation might be expected, perhaps, to triple the useful life of the tube.

Realizing the value to the experimenter and the dealer of a simple device for testing and reactivating tubes, the General Radio Company has developed the Type 388 Tube Reactivator which operates from 110-volt, 60-cycle A. C. No batteries or other equipment are necessary to the operation of this instrument. Sockets are provided whereby the correct voltage for testing, flashing, and "cooking" are automatically obtained without any adjustments whatever. The operation is, accordingly, extremely simple and the results quite satisfactory. The emission of the various oxide-coated filaments can likewise be tested on the Type 388 Tube Reactivator, but these tubes can not, of course, be reactivated.

The Type 413 Beat-Frequency Oscillator

In measuring loudspeakers and audio frequency systems, it is often desirable to move through the entire frequency range quickly. The conventional type of vacuum tube oscillator although it may be so designed as to be continuously variable, requires the adjustment of a number of controls in varying the frequency through the entire audio range. As the change in frequency involved is large, about five hundred to one, it cannot be obtained by the rotation of a single instrument of practicable construction. If the measuring frequency is obtained by beating two oscillators together, a small percentage change in frequency of one of the oscillators will cause a relatively large change in the beat frequency.



Supplementing its oscillators of conventional type, the General Radio Company is manufacturing a beat frequency oscillator for the audio frequency range. The Type 413 Beat-Frequency Oscillator consists of two oscillators, a detector, and an amplifier tube. The frequency of one of the oscillators is fixed at about 60 kilocycles, while that of the other is variable from approximately 50 to 60 K. C. Both oscillators are coupled to the grid circuit of the detector tube. The oscillators are so constructed and shielded as to maintain a constant frequency over long periods without adjustment. The system of coupling the oscillators to the detector, supplying it with a low voltage from each oscillator is such that tendency of the two oscillators to pull into synchronism as zero beat is approached is eliminated. The detector output is fed through a Type 373 impedance coupler giving nearly constant amplification over the wide range of frequencies used, to an amplifier tube. The output of the oscillator is taken off across a 10,000 ohm resistor used as a voltage divider, permitting the adjustment of the output voltage without changes in the oscillator circuit proper which might affect wave-form or frequency.

Three variable capacities will be seen in the diagram. One of these is a small compensating condenser mounted inside the instrument. The purpose of this condenser is to correct for any slight inaccuracy in the fixed condenser in this circuit. The frequency is changed by means of two other variable condensers, the main tuning unit of 500 MMF maximum capacity, and a micro - condenser shunted across it for fine adjustment.

The Beat-Frequency Oscillator is designed for use with either WX-12 or UX-199 tubes, space being provided in the cabinet for three one and one-half volt dry cells and three twenty-two volt "B" batteries. UX-201A tubes may be used with an external battery if desired. A five-volt Weston meter on the panel, and a rheostat inside the cabinet permit the adjustment of the filament voltage to the rated value. The Type 413 oscillator has an output of about two and one-half volts. The variation in output voltage over the frequency range is slightly less than 10%. The wave-form is satisfactory for most purposes, the total of harmonics being at a maximum less than 4% of the wave in voltage.

The Type 413 oscillator is useful in the measurement of all devices intended for operation in the audio frequency range. It is particularly helpful in the study of loudspeaker response curves, as the complete frequency range at practically constant intensity is available by one half revolution of the main dial so that peaks or hollows in the response of the speaker are immediately evident. Any tendency to blast at particular frequencies is quickly revealed.

The instrument is licensed under Patent No. 1,113,149 by the Radio Corporation of America for experimental laboratory use only where no commercial features are involved.

The price of the Type 413 Beat-Frequency Oscillator, without tubes and batteries is $210.

Matching Impedances

When two elements in an electrical system are connected together, the efficiency of the system depends to a large degree on the relations existing between the impedances of the units coupled together, and some form of "adjusting" transformer is required. Questions asked in recent correspondence would seem to indicate that there is some confusion as to the principle of such devices.

The design of the coupling device depends on whether it is desired to transfer the maximum of voltage, current, or power, to the receiving unit. In the conventional vacuum tube amplifier, the object is to obtain as high a voltage as possible in the grid of the succeeding tube. The load on the coupling device is practically an open circuit. In this case, the object is to obtain as high an input impedance in the coupling device as possible. As the transformer operates with its secondary practically open circuited, the primary impedance with secondary open circuited is a true indication of whether or not the device is suited for a given use.

There are many cases where it is required to get a maximum transfer of power occurs when the impedance of the receiving circuit equals that of the source. It is frequently necessary to use a transformer to obtain this optimum transfer in places where the source and load are of widely differing impedances. There seems to be a widespread misunderstanding of the function of transformer in this case. Frequently orders are received for a transformer to have "10,000 ohms primary impedance, 5,000 ohms secondary impedance." What is wanted is a transformer suitable for use between impedances of 10,000 and 5,000 ohms. A transformer having open circuit impedances as specified would be entirely unsuited to this use. The transformer is not "matched" to the load impedances, its function is to match the load impedances to each other. The object is not to get the maximum power into the transformer, but to get it into the load. For this purpose the impedance ratio, not the actual impedance is the important factor. The actual open circuit impedance is of importance, since it forms a load in parallel with the useful load. If a transformer with a 10,000 ohm primary were supplied for working out of a 10,000 ohm source, half of the available power would be lost in the transformer. The open circuit impedance must be several times the impedance of the loads being coupled together for an efficient transfer. A transformer, for example, for coupling a 10,000 ohm tube impedance to a reproducer should have 50,000 ohms or more, open circuit primary impedance.

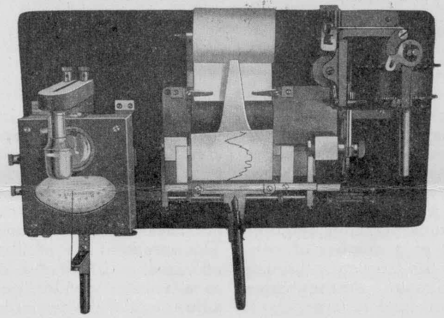
What Speaker?

Frequently we are asked the question: "What speaker do you recommend for me to use?" or "Should I buy the —— speaker?" This is one of those questions like: "Have you stopped beating your wife?" which cannot be answered directly without embarrassment. Leaving out of the question the fact that tastes differ to the extent that a speaker, which is shown by every test to be an acoustical atrocity, will have its enthusiastic admirers, while a high quality reproduction is condemned as "boxy" or "muffled," the answer is not simple, because the behavior of a speaker depends to a great extent on the amplifier with which it is used. It might be thought that the effect of the speaker and amplifier are directly additive, that a good speaker will sound better even on a poor amplifier than an inferior speaker. Such does not prove to be the case. Some speakers are, of course, so bad that they are terrible with any amplifier. Between a great many speakers, however, the amplifier will determine the choice. A perfect amplifier would, of course, sound best with a perfect speaker, and, as a rule, the better the amplifier, the better the speaker which will give best results. This can be very readily observed by means of an interesting experiment which does not require a great deal of apparatus. A simple filter is connected between the output of a high quality amplifier and a quick throw switch by means of which the speakers are to be compared. The inductance coil of the filter should be so constructed that it is possible to move the iron core in and out changing the cut-off frequency of the filter. With the filter removed, tune in a station having a high quality output and classify the speakers under test in order. If the amplifier and broadcast are of good quality, this test will probably give results indicative of the actual merit of the speakers per se. This is not always the case, as the type of music received also affects the result. As the iron in the filter is moved in and out, cutting out different parts of the frequency range, it will be found that first one and then another of the speakers will be selected as giving the most pleasing effect.

If you live in a large city, where there are a number of broadcast stations, the filter will be unnecessary, simply turn to stations of varying degrees of perfect or imperfect output.

Beauty, it is said, is in the eye of the beholder, so quality lies in the ear of the auditor—and lies and lies.

An Instrument for Making Graphic Record of Signal Strength Variation



Among the many scientific instruments made by the General Radio Company is the Type 289 Fading Recorder, which was developed for use in a study of radio transmission phenomena begun by Mr. G. W. Pickard several years ago. A detailed account of the earlier part of the work was published by Mr. Pickard in the Proceedings of the Institute of Radio Engineers, Vol. 12, No. 2, but it may be of interest here to give a brief description of the instrument and how it is used.

The function of the Fading Recorder is to make an accurate graphic record of carrier waves from more or less distant broadcasting stations. This record shows very clearly the variation in signal intensity (or fading as it is more usually called). Almost any type of radio receiver which is sufficiently sensitive may be used and a D. C. galvanometer which gives a full-scale deflection of only a few millionths of an ampere is so connected that the carrier, which is rectified by the detector tube in the receiver, or by an additional rectifier (tube or crystal), may be read directly on the galvanometer. The latter, which is clearly shown in the photograph, is mounted in such a way that a pointer may be moved back and forth over it, by hand, to follow the galvanometer needle as it fluctuates under the influence of fading. The pointer is connected through a system of levers to a fountain pen, which traces a curve on a paper tape, the curve shown in the picture being more or less typical of reception from a distant broadcasting station. The drum over which the paper passes is rotated once in twenty minutes by a small synchronous spring motor as illustrated, which is intended for use where alternating current is not available. The small electric lamp shown not only illuminates the galvanometer dial but by casting a shadow of the pointer and of the galvanometer needle makes it easy to keep the two in coincidence, thus avoiding any effect of parallax.

Although this type of recorder was designed for records of rather short duration, it has been found that it may be used for an hour or more without undue fatigue, although for such records one of the fully automatic types of recorders is preferable if the higher cost is not an obstacle.

It may be mentioned that it ordinarily makes no difference whether or not the carrier-wave is modulated, because the variations due to modulation take place, of course, at audio frequencies, that is, at tens or hundreds of cycles per second, and the galvanometer is much too slow to follow these, so that they are averaged out. In the present-day operation of most broadcasting stations, the antenna current remains practically constant, irrespective of modulation, and it is only rarely that a slight change may be noticed from that cause. Telegraph signals, broken up into dots and dashes, are of course not suitable for recording in fading investigations, but the broadcasting stations are an ideal source for this purpose.

During the past month our attention has been called to several errors in our mailing list. We are anxious to keep our list as nearly perfect as possible. We would, therefore, appreciate your co-operating with us to the extent of notifying us if there is any error in your name or address on the envelope in which this issue of the Experimenter was mailed.

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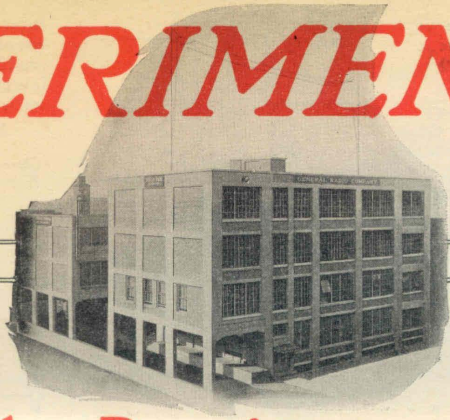
VOL. 1 NO. 11 MAY, 19



A Review of Coupling Methods

By C. T. BURKE, Engineering Department

While methods of coupling between vacuum tubes at audio frequencies may be broadly divided into but three classes; resistance, impedance, and transformer coupling, these methods contain many subdivisions which raise the total number of possible methods of coupling to a surprising figure.

FIG. A.

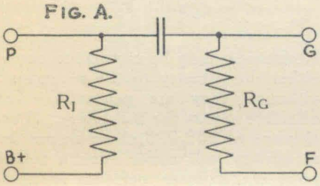
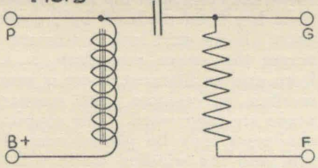


Figure A is the usual resistance coupled amplifier. R, which determines the input resistance of the device should be several times the plate resistance of the tube out of which the coupling device is working. The size of the coupling condenser and of R_G may vary over a considerable range, depending upon the characteristic desired. For an efficient voltage transfer, R_G should be large compared with the input impedance of the tube. The capacity of the condenser will depend on the frequency range it is desired to cover, and on the value of R_G. It may be one-half to one microfarad where the frequency range extends well below one hundred cycles. A large condenser is sometimes viewed with disfavor on the ground that it causes "blocking" in the amplifier. Blocking will not occur, however, unless the grid of the amplifier tube is allowed to become positive. Proper biasing will prevent this. The principal advantage of resistance coupling is well known. It is the method of coupling by means of which a good frequency characteristic may be obtained with least first cost. It has, however, the rather serious objection that the high input resistance causes a large drop in voltage between the source of plate power and the plate of the tube. Unless a rather high voltage is used at the source, the tube is not operated at the best part of its characteristic, and harmonics may be introduced. In all types of coupling devices where a condenser is used in the grid, care should be taken to keep the capacity of the condenser to ground at a low value.

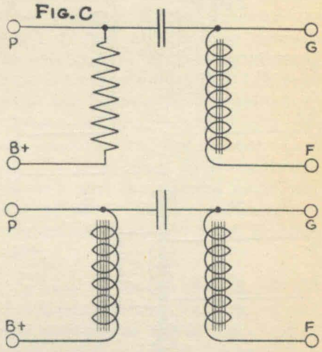
FIG. B



The arrangement shown in Figure B is derived from that of Figure A by substituting an impedance for a resistance as the input device. This has the advantage of a comparatively low voltage drop, and with proper design, can be made to cover any desired frequency range. The impedance of the choke should be several times the plate impedance of the preceding tube at the lowest frequency which it is to amplify.

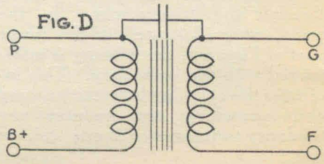
The methods of Figure A and B can be modified as shown in Figure

FIG. C



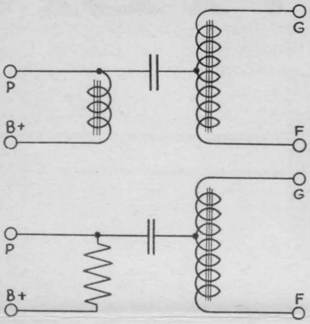
C. In these circuits, an impedance is used in place of a resistance in the output circuit. This arrangement is recommended where there is danger of grid current flowing momentarily, as on occasional loud signals, particularly in the last amplifier stage.

FIG. D



In the circuit of Figure C, the plate and grid coils are generally on different cores and are not magnetically coupled to each other. In Figure D, both coils have been put on the same core to form a 1:1 transformer, but the condenser has been retained and provides sufficient capacitative coupling at high frequencies to reduce any tendency toward resonance at high frequency due to magnetic leakage.

FIG. E



In the circuit of Figure E, advantage is taken of the step-up in voltage obtained by the auto-transformer connection. This feature increases the volume per stage, and may be combined with any of the systems of Figures A to D.

FIG. F

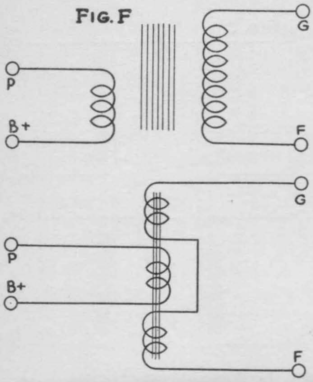
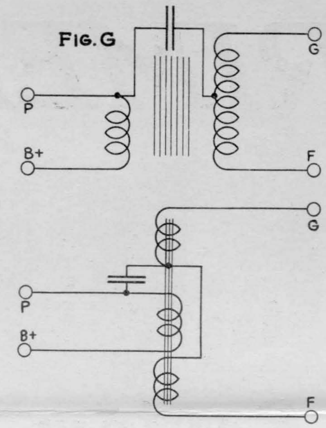


Figure F is the usual form of transformer. Proper design calls for an input impedance which is high in comparison with the source out of which it is working. The great advantage of this type of coupling is, its superior efficiency in consequence of the gain in voltage in passing through the transformer. In the transformer illustrated in the lower part of Figure F, the primary is interleaved with the secondary. This increases the coupling between primary and secondary, and reduces any tendency to resonance due to leakage flux.

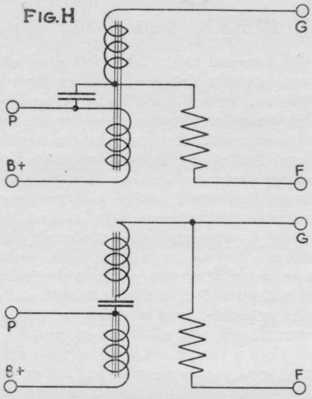
Figure G, represents an adaptation of the principle of Figure D to a transformer of other than unity ratio. The condenser is connected to the secondary at the point where the secondary induced voltage is equal to the primary impressed voltage. The presence of the condenser reduces

FIG. G



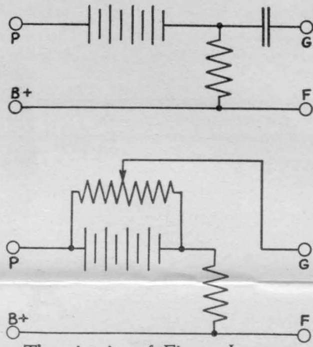
any tendency toward a resonant peak at the higher frequencies. This connection may, of course, also be used in conjunction with an interleaved primary.

FIG. H



In the circuit of Figure H, the portion of the transformer secondary between the condenser tap and the filament has been replaced by a resistance. If the grid leak is connected across the entire secondary, i. e., from grid to filament, there is some sacrifice of volume, but resonant peaks are suppressed. The coupling condenser may be placed near the grid and the winding made with a tap, instead of in two sections. There is some advantage in placing the coupling condenser as shown in Figure H, as capacity to ground from the large (physically) coupling condenser is reduced.

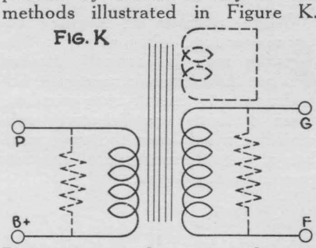
FIG. I



The circuits of Figure I are conventional for amplifying direct voltages.

Resonant peaks may be suppressed by means of any of the methods illustrated in Figure K.

FIG. K



Resistances may be connected across either the primary or the secondary, although they are generally more effective across the secondary. A resistance of 200,000 ohms across the secondary will make even a rather poor transformer perform satisfactorily. Amplification will, of course, be greatly reduced. Resonant peaks will also be reduced by the short-circuited third winding.

For some purposes, it is not desirable to pass a wide band of frequencies. In such cases, tuned coupling devices as shown in Figure L should be used. The push-pull amplifier shown in Figure J has several advantages. One is greater un-

FIG. J

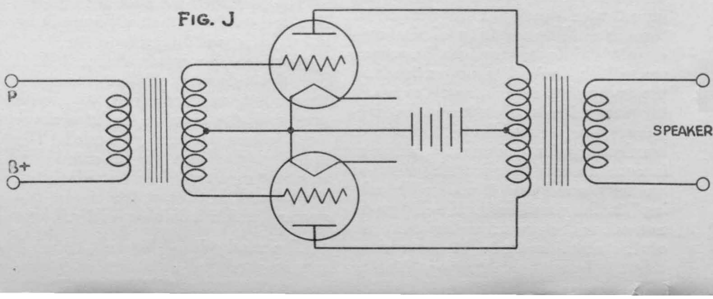
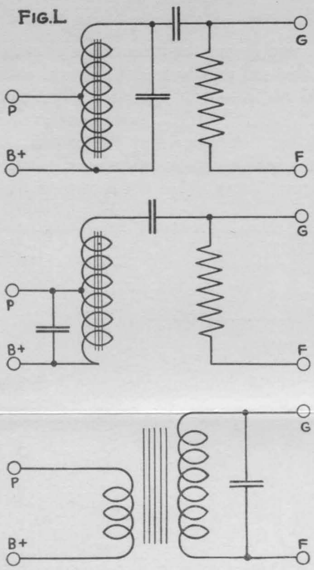


FIG. L



distorted output than is possible with two tubes in parallel or a single tube. Even harmonics are eliminated. As most of the harmonics introduced by tube overloading are even, this permits operation of the tubes at heavier loads than is possible with the usual system. Another advantage is the elimination of D. C. magnetization of the output transformer core, as the direct current flows in opposite directions from the two tubes. Auto-transformers may, of course, be used in the push-pull amplifier.

For a more complete discussion of these methods of coupling, the reader is referred to the following:

Telephone Systems and Audio Frequency Apparatus. Cohen, Aldridge and West. Proc. Wireless Sec.—Inst. of E. E. Sept., 1926.

The Performance and Properties of Telephone Frequency Intervalve Transformers. D. W. Dye—Experimental Wireless. Vol. 1, Page 691. 1924.

Vacuum Tube Amplification. S. E. Anderson. Proc. Radio Club of America. December, 1922.

Transformer Coupled Audio Amplifiers—A. W. Saunders, Proc. Radio Club of America. Sept., 1926.

Telephone Transformers—W. L. Casper—Proc. A. I. E. E. Page 196, Vol. 43. 1924.

Low Frequency Intervalve Transformers—P. W. Williams, Proc. of Wireless Section, Inst. of E. E. September. 1926.

The Type 411 Synchronous Motor

In checking a source of constant frequency current, great accuracy may be attained by using the source to drive a synchronous motor, and counting the motor revolutions over a long period. Synchronous motors may be built which will operate properly at audio frequencies. Higher frequencies may be checked by means of stepping down the frequency by means of a series of oscillators, with harmonics of the lower frequency oscillators adjusted to synchronism with the fundamentals of those of higher frequencies.

The Type 411 Synchronous Motor is designed for use in calibrating frequency standards by this method. The motor drives a clock movement and when supplied with two-tenths of a volt-ampere at 1000 cycles will keep correct time. The motor will run from any source of 500 to 1800 cycles providing two-tenths of a volt-ampere.

The motor is not self-starting, but must be brought up to correct speed gradually. This is easily done by spinning the corrugated portion of the shaft with the finger. The motor will not synchronize if it is run too fast and then is permitted to slow down by its own friction, as the pole pieces do not have a sufficiently strong magnetic effect to overcome the drag thus produced. A Neon tube, operated through a transformer from the source, is placed beneath the periphery of the rotor. Looking through the rotor teeth at the Neon tube, the teeth will appear to be stationary when the motor is in synchronism. The two grooves in the rotor should be about half filled with mercury to prevent hunting which is otherwise likely to occur with this type of motor.

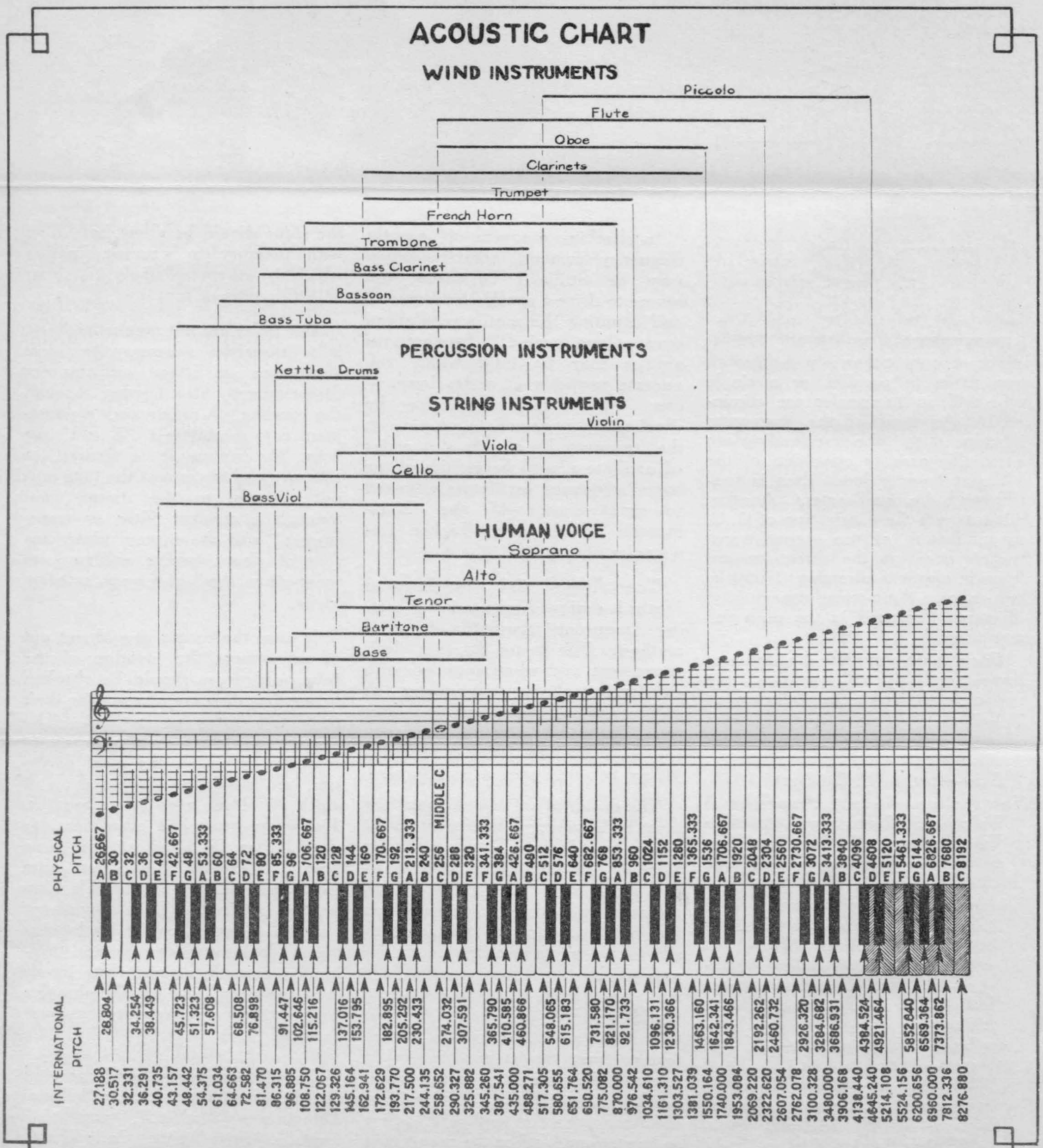
The poles are not magnetized and it is therefore necessary to have about ten or fifteen milliamperes direct current also flowing through the winding. A satisfactory arrangement is to modulate a UX 171 tube from the source it is desired to measure and to connect the tube output directly to the motor (not through a speaker filter or transformer) and the normal plate current of about twelve milliamperes magnetizes the poles very satisfactorily.

In case the motor should get out of adjustment the location of the four pole-pieces should be checked to see that they are all opposite their respective rotor projections. The upper and lower bearings are of sapphire in which the steel pivots run, and should be given a drop of clock oil about once in six months. The worm gears and other bearings should also be oiled at the same time. The rotor should run quite freely but without appreciable play in the bearings. This adjustment may be changed readily by loosening the lock-nut at the top and turning the screw in or out. The jewels are mounted in small plungers backed by a spring to prevent damage.

Specifications of the Type 411 Synchronous motor are as follows: Dimensions 8″x7″x5″, weight 7 pounds. Price $130. Code Word: "SEDOY".

Correlated Acoustic Chart

This chart represents the relation between the musical scale and piano key-board, giving the frequencies of each note in terms of complete vibrations per second according to the two principal scales and pitches used in musical and scientific work, viz: The INTERNATIONAL equally tempered scale based on A=435 complete vibrations per second, which is generally used by musicians—the SCIENTIFIC or PHOLOSOPHICAL scale—generally used by physicists—based on MIDDLE C=256 complete vibrations per second. It also shows the correlated range of the various instruments within the orchestral range and the different voices which constitute the vocal range. The shaded keys are not included on a standard piano key board. The extreme organ range not shown on the chart is from 16 cycles to 16, 384 cycles, PHYSICAL pitch.



PUBLISHED THROUGH THE COURTESY OF WAVERLY MUSICAL PRODUCTS CO. INC., L. I. CITY, N.Y.

For those who are keeping a continuous file of the various issues of the "Experimenter" and would like a copy of the Acoustic Chart to mount on a piece of stiff cardboard for handy references, we have extra copies which we will be glad to send on request.

Printed in U. S. A.

The GENERAL RADIO EXPERIMENTER

VOL. 2 NO. 1 JUNE 1927

IMPORTANT NOTICE

This issue of the "Experimenter" is the First Anniversary Number. Just a year ago Volume I, Number 1 was published and a copy sent to every name on our mailing list.

With the first issue of the "Experimenter" we inclosed a post card to be returned to us properly filled out if future copies of the "Experimenter" were desired. So many cards were returned and new names added that today our mailing list is more than double what it was in June 1926.

We are about to make up our new mailing list for another year. THIS LIST WILL BE MADE UP FROM RETURNED POST CARDS *ONLY*. If you wish your complimentary subscription for the "Experimenter" to continue, please return the inclosed post card promptly, *regardless of whether you have already sent us a card or written us previously.*

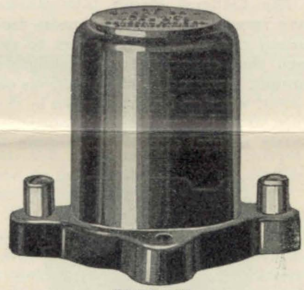
Owing to such a large list, only a few extra copies are available and it will be *impossible to obtain back copies later than a month after issue.*

The Design and Use of the Radio Frequency Choke

By *HORATIO W. LAMSON*, Engineering Department

The amount of radio frequency amplification which can be employed successfully in the design of a broadcast receiver is very largely limited by the regenerative or "feed-back" tendency of such an amplifier. If the arrangement of the circuits is such that there exists even a small amount of inductive, capacitive, or resistance coupling between the first and succeeding stages a certain portion of the energy from the last tube may be fed back onto the grids of the previous tubes, giving rise to the phenomenon of regeneration. A limited amount of regeneration is beneficial as it effectively reduces the resistance losses of the inter-tube coupling elements. It is well known, however, that an excess of regeneration will cause the whole amplifier system to go into a state of sustained oscillation, which is fatal to its proper operation.

This tendency towards self-oscillation may be combated in a number of ways, one of the most important being the so-called process of "neutralization," whereby a certain amount of energy is fed backward through the amplifier but with a reversal of phase so that it tends to oppose the natural regeneration of the circuits. This is the principle employed in the popular neutrodyne receivers.



TYPE 379
Radio Frequency Choke

Excessive regeneration may also be prevented to a certain extent by shielding the individual stages, by controlling the grid bias of the amplifier tubes, or by the deliberate insertion of resistance into the individual tube circuits.

Another method of accomplishing the same result consists of more effectively separating the radio frequency circuits of the tubes from each other. The plate circuits of these tubes are almost invariably fed from the same B battery. This battery has necessarily a certain amount of resistance, depending upon its form and condition, which, being common to the plate circuits of the tubes, affords a source of resistance coupling between them if the radio frequency currents are allowed to pass through this battery. When, however, the individual plate circuits are supplied with radio frequency chokes, which prohibit the radio frequency currents from traversing the common B battery, this resistance coupling with its regenerative tendencies can be reduced considerably.

Some of the methods for accomplishing these results are shown on the following pages. The radio frequency choke marked "379" consists merely of a small inductance coil which has a very large impedance at radio frequencies so that it effectively blocks the passage of radio frequency currents. At the same time, its resistance to the steady emission current of the tube is low, so that but little B battery voltage is wasted across it, while its impedance at audio frequencies is sufficiently small to offer no appreciable hindrance to voice frequency currents.

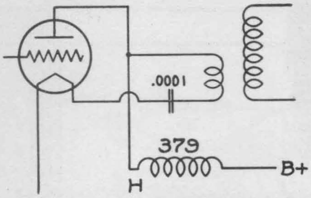


Fig. 1

Figure 1 shows the use of such a choke in the plate circuit of a radio frequency amplifier tube. On account of the choke the high frequency currents in the plate circuit are forced to pass through the primary of the transformer and thence through the condenser directly back to the filament of the tube, while the emission current of the tube passes through the choke to the B battery. The condenser, which offers no great impedance to the radio frequency is, of course, necessary to prevent the B battery from short circuiting to the filament. Figure 2

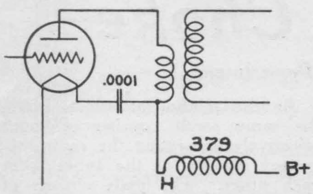


Fig. 2

shows essentially the same circuit except that here the emission current passes through the primary of the transformer.

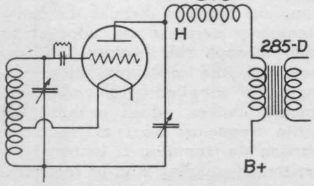


Fig. 3

Figure 3 illustrates how the choke may be placed in the circuit of a regenerative detector to keep the radio frequency currents out of the audio amplifier and the B battery. The emission current of the tube, together with the rectified audio frequency currents, pass readily through the choke to the primary of the audio frequency transformer. Regeneration of the detector is, in this case, controlled by the variable by-pass condenser in the plate circuit.

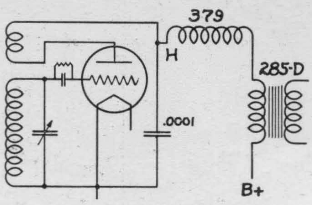


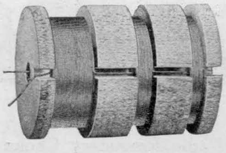
Fig. 4

Figure 4, likewise, shows the use of the choke in the plate circuit of a detector of the familiar tickler coil type.

Many other uses of a radio frequency chokes will suggest themselves to the experimenter.

The construction of a successful radio frequency choke consists of more than merely winding a coil to a sufficient inductance so that it will offer an effective barrier to radio frequency currents. The coil must also be wound in such a manner that its distributed capacity will be very low, else the capacity between the two end portions of the windings may be sufficient to pass the radio frequency currents around the inductive impedance and defeat the whole purpose of the choke.

The General Radio laboratories have recently developed a radio frequency choke which, in order to reduce this capacity to a negligible amount, is wound in three sections on a small wooden bobbin shown in the illustration below which is approximately natural size. This bobbin is



then sealed into a moulded bakelite case and the coil extremities brought out to two terminal posts as shown in the illustration on the front page. The winding sections are respectively $\frac{5}{16}$, $\frac{1}{8}$ and $\frac{1}{16}$ inches in width. The end of the winding in the smallest section is brought to the terminal marked H, and this terminal should be connected to the "high potential" or radio frequency side of the circuits as indicated on the diagrams.

In order to find the best relation between inductance and distributed capacity a number of identical bobbins were wound with different sizes of wire and tested for distributed capacity in the following manner: An oscillator circuit of the Hartley type was set up as shown in Figure

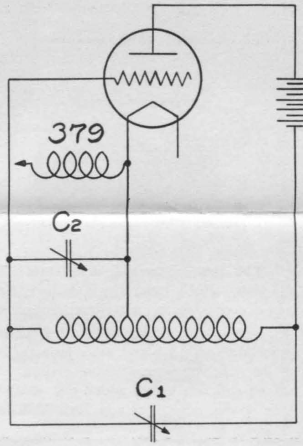


Fig. 5

5. A small calibrated micro-condenser C_2 of 8 MMF capacity was connected between the grid and filament. This had a slight effect upon the tuning of the oscillator circuit. The oscillator was first accurately tuned to a given wavelength with the condenser C_1 by adjusting for zero heterodyne beats against a separate crystal-controlled oscillator not shown. The choke under test was then connected between the grid and filament in parallel with C_2. If now the choke coil had an effective positive capacity at the frequency in question it would, of course, raise the wavelength of the oscillator slightly. The oscillator would then be retuned to the original wavelength by reducing the variable condenser C_2 by an amount equal to the effective capacity of the radio frequency choke. From the calibration of C_2 the capacity of the choke could thus be measured directly. On certain occasions it was found that the circuit could be retuned only by increasing the value of C_2 after the choke was added, indicating that the choke had a negative capacity effect.

The results of these tests at various wavelengths are shown in the following table which lists the effective capacity in micro-microfarads of several samples at different wavelengths.

RADIO FREQUENCY CHOKES.

Wavelength	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9
20	NG	3.5	NG	NG	3.2	1.9	2.4	NG	NG
40	3.1	3.4	1.7	1.8	3.1	2.3	2.5	4.2	2.5
90	.6	2 9	3.0	3.0	3 2	-2.9	3.0	4.3	3.6
160	1.9	3.9	-6 6	-6.0	4.0	1.0	1.6	4.2	3.7
320	8.4	.6	2.9	3.1	1.0	8.8	3.7	4.0	3.6
640	-2.3	2.4	-10.8	-12.0	3.5	-2.2	2.9	3.2	3.2
L=M.H.	14.5	152	7.8	7.9	153	15.3	64	92	243
Winding	1500T No. 36SCC	4800T No. 36 En	1075T No. 34SCC	1075T No. 34SCC	4800T No. 36 En	1500T No. 36SCC	3000T No. 34 En		

A winding identical with No. 7 has been chosen as the General Radio R. F. choke Type 379. This has an approximate inductance of sixty millihenrys and, as seen from the table, is an effective choke for all wavelengths from twenty meters to considerably above the upper limit of the broadcast band. It may, therefore, be used to advantage in short wave receivers as well as broadcast receivers. The resistance of this instrument is about 140 ohms and its current rating 90 milliamperes, corresponding to a DC power rating of 1⅛ watts. This current rating is for continuous use. For intermittent use, however, as for instance in a transmitter which is being keyed, the rating may be doubled with safety. The choke may, therefore, be used with success in the construction of low power amateur transmitting sets where the above ratings are not exceeded.

Realizing the demand for a radio frequency choke of higher current rating for use in amateur short wave transmitters, a lower resistance coil has been developed, wound on the same bobbin and incased in the same moulded form. The experimental data, obtained in a manner identical to that described above, are given in the following table:

Wave Length	No. 10	No. 11	No. 12
20	3	2.1	2
40	1	2.9	2.2
80	0.5	0.8	3.0
100	NG	3	0.9
160	3.4	-1.1	NG
Inductance	2.15	8.2	4.27
MH	950 T	1830 T	1340 T
Winding	No. 28 SCC	No. 32 SCC	No. 30 SCC

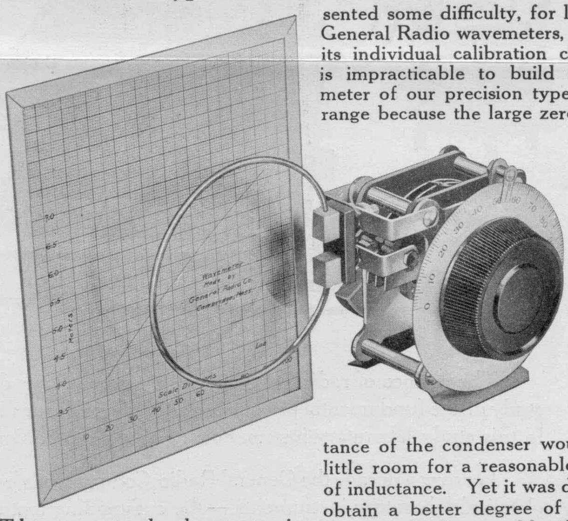
The winding No. 11, which further careful study showed to have no "dead spots" between 15 and 200 meters, was chosen as the standard Type 379-T choke. This type has an inductance of 8 millihenrys, a resistance of 34 ohms, a continuous current rating of 200 milliamperes, corresponding to a power rating of 1.4 watts.

Either type of choke has a list price of $2.00.

Proper Position for Volume Control

Diagrams sometimes show a high variable resistance across the loudspeaker terminals, or across the primary or secondary of the transformers. The use of a volume control in this portion of the circuit is open to the objection that it permits overloading of the detector and one or both of the amplifier tubes. The proper position for a volume control is before the detector. With a control so placed, the volume even on local signals can be reduced to a point where the detector and amplifier are not overloaded.

The Type 458 5-Meter Wavemeter



The recent developments in transmission at 5 meters (60,000 k c.) have made it desirable to have an accurate wavemeter covering that wavelength. Even when schedules were arranged, it was often the case that the transmitter and receiver were so far out of tune that results were impossible.

The Type 458 wavemeter is supplied unmounted, having only brackets to support the condenser in an upright position. The condenser is of the usual soldered plate, metal end-plate type, having a maximum capacitance of 50 MMF. The importance of soldered plates at this high frequency can hardly be overemphasized. The coil consists of a single turn of ⅛″ copper tubing, and is connected to the condenser by means of the convenient General Radio plugs. The coil is silver plated. A four-inch dial and indicator completes the wavemeter. It is found that the metal end-plates so completely shield the condenser that hand capacity is not troublesome.

The calibration of this meter presented some difficulty, for like other General Radio wavemeters, each has its individual calibration chart. It is impracticable to build a wavemeter of our precision type for this range because the large zero capacitance of the condenser would leave little room for a reasonable amount of inductance. Yet it was desired to obtain a better degree of accuracy than would be possible if another Type 458 wavemeter were used as a standard. This difficulty was overcome by first roughly calibrating a 458 by the usual harmonic and extrapolation method. Then an oscillator was carefully set with a Precision Wavemeter to 20 meters, which is well within the precision range. Another oscillator was then adjusted to approximately 5 meters by the roughly calibrated 458. When the second oscillator was shifted slightly, a beat note was found, and zero beats gave an accurate setting of 5 meters by the roughly calibrated 458. Several points taken by this method gave an accurate calibration curve. All Type 458 Wavemeters are now calibrated against a Precision Standard.

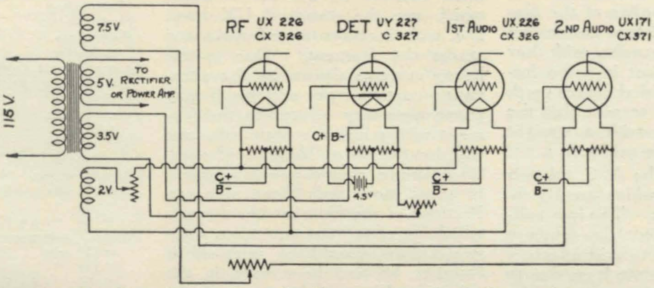
The Type 458 5-meter wavemeter is obtainable from the General Radio factory only. It will be delivered post paid and insured anywhere in the United States upon receipt of $8.00, or to any foreign country upon receipt of $9.00.

The GENERAL RADIO EXPERIMENTER

VOL. 2 NO. 2 JULY, 1927

Complete A. C. Operation a Practical Reality

By C. T. BURKE, Engineering Department



The above diagram shows the filament wiring for A. C. operation of popular four tube type of receiver

The principal radio trend of the season just past has been toward the elimination of batteries. Many satisfactory plate supplies have been developed, but the problem of filament supply has offered more difficulty. Larger currents are required for filament than for plate supply, and this means greatly increased expense in the rectifier and filter circuit. Then too, many of the plans proposed for batteryless filament lighting required rewiring of the tubes in series. EXPERIMENTER readers may recall that an analysis of the filament supply problem appearing in this publication last October concluded with the suggestion that the problem of batteryless filament operation seemed to rest upon the manufacturers of tubes rather than upon the manufacturers of accessories.

The development forecast in that article has come to pass with the recent announcement of tubes for alternating current filament supply by several manufacturers. Many of these tubes will be available in the next few months, and the batteryless receiver will probably be the outstanding development of the coming radio season. This does not imply immediate obsolescence of present receivers. The new tubes will have plate characteristics similar to those now in use, and the present types of tubes will continue to be supplied. The trend will, however, undoubtedly be toward the A. C. filament tubes.

Two types of A. C. filament tubes are to be supplied, representing different methods of attack on the problem of A. C. filament operation.

In the conventional type of tube supplied for direct current operation, the filament forms a part of two circuits. The battery circuit through the filament is for the purpose of heating the filament to produce electron emission. This circuit is auxiliary to the main function of the tube, but the filament also forms one side of both input and output circuits of the tube.

If alternating current is supplied to the filaments of ordinary tubes, a hum will result. Several sources contribute to the hum. As the current through the filament changes during the alternating current cycle, varying from zero to maximum, the temperature of the filament, which depends on the current through it is also changing. The change in filament temperature results in a cyclic change in the tube characteristics which in turn produces a hum at twice the frequency of the supply. A certain amount of hum is due to capacity effect between the tube elements and to voltage drop along the filament. Another appreciable source of hum is the grid effect of one side of the filament on the other. The filament of most tubes (except the 199 tube) is triangular in shape (less the base). When direct current is applied to the filament, conditions are stable, and the grid effect of one end of the filament on the other introduces no disturbance. When alternating current is applied to the filament, the grid effect is variable. As the current increases through the filament one end of the filament is increasingly negative with respect to the other, and the emission from that end of the filament is reduced, since the other end is more positive and attracts a portion of its emission current. A half cycle later the two ends of the filament are reversed, and the effect repeats. A hum at twice the supply frequency results.

In one type of alternating current filament tube, the design is similar to the direct current type except for the construction of the filament which is short and heavy, taking materially more current than the modern direct current tubes and operating at low voltage. An advantage of the heavy filament is that it retains heat longer than the present type, i.e., there is less heating and cooling as the current goes through its cycle, the heat carrying over from one cycle to another. In fact, sufficient heat remains to produce audible signals for a few seconds after shutting off the current. It might be expected that such a filament would take longer to reach its operating temperature. This proves to be the case, and there is an appreciable wait between the turning on of the current and the appearance of the signals. It may be noted in passing that some of the direct current tubes have the characteristics of slow heating and cooling of the filament. The WX 12 type can in fact be used with fair results, with low A. C. on the filament in radio frequency stages, provided care is used. It is also interesting to note that the 199 type of tube, with a straight filament, shows little grid effect.

The filament of the A. C. tubes is short and straight, which greatly reduces the grid effect. The low voltage across the filament also tends to reduce the hum due to grid effect.

In order to eliminate hum due to the voltage drop through the filament the grid and plate returns must be connected at the average potential of the filament, i.e., the potential of the center point. Unless this is done a pronounced hum having the same frequency as the source of current will be produced by a periodic fluctuation of both the grid bias and plate voltage. The most satisfactory means of obtaining this connection is by means of a center-tapped resistance across the filament terminals of the tube. The center of the resistance is necessarily at the same potential as the center of the filament.

Tubes of the heavy filament type are generally made to fit the standard UX type of socket. This type of tube is suitable for either radio or audio frequency amplifier work. Some manufacturers do not, however, recommend tubes of this type for use as a detector.

In another type of tube for alternating current operation the two circuits which use the filament of the direct current tubes are separated. The cathode is heated from a separate heating element inside the cylindrical electrode, while an additional terminal is provided for the C+ and B— connection and the tube has therefore a five-prong base, requiring a special socket. This type of tube also requires a center-tapped resistance across the heating element. The center point of the resistance may be grounded in this case. When the mid point of the potentiometer is grounded, the setting is rather critical for best results. Another less critical method is to connect a 4.5 volt battery between the center tap and the cathode terminal. The negative of the battery is joined to the center tap. This type of tube is particularly recommended for use as a detector.

No power-tubes are listed among the new alternating current filament tubes, due to the fact that raw A. C. can be used with perfect satisfaction on the filaments of present last stage tubes. The output tube should always be the 112, 171, or 210 type. These tubes are connected in the same manner as the A. C. tubes which use the standard UX base, i. e. with a center-tapped resistance across the filament. Due to the heavy currents drawn by the alternating current types of tube, it may prove necessary to replace the filament wiring in some multi-tube sets with heavier wire. Number 18 wire, for example, should not be required to carry more than three amperes. Portions of the filament bus through which greater current than this would flow should be replaced if Number 18 had been used in the original wiring. As some of the new tubes draw two amperes each, quite large currents may flow in parts of the filament wiring carrying current for several tubes.

Another change which is necessary in all cases where a set is altered to accommodate the new tubes is the shifting of the plate and grid return connections. In the direct current types of tube the C+ and B— connections are made to one side of the filament. When using the five-prong type of A. C. tube, the C+ and B— connections are made to the fifth prong. In the other type of tube, using the UX base, the center of the resistance across the filament is used for the C+ and B— connections.

All the new tubes operate on low voltage and a transformer is required between the line and the tube. The transformer should be designed to provide a higher voltage than the tube requires, to allow for voltage drops in the wiring. Rheostats will be required, but once set no further adjustment will be necessary, so that rheostats may be placed behind the panel.

While variations may be necessary to meet the requirements of individual receivers, the diagram of filament wiring for a typical four-tube receiver as shown on the front page will be found a useful guide in changing over a receiver for the new tubes. No changes will be required except in the circuits shown.

Current Carrying Capacity of Wire (Rubber Covered)

This data will be found helpful in determining the size of wire to use in rewiring filament circuits for A. C. operation:

Size	Diameter (Mils)*	Current
12	80	20 amperes
14	64	11 "
16	51	6 "
18	40	3 "
20	32	1.5 "

*Mil=0.001 inch.

Data on New A. C. Tubes

The following are characteristics and specifications of the new A. C. tubes.

UY-227 or C-327 Detector Tube
(Separate Heater Type)

Heater voltage	2.5 volts A.C.
Heater Current	1.75 amperes
Plate voltage	
as detector	45 volts
as r. f. & a. f. amplifier	90-135 volts
Maximum voltage permissible	180 volts
Grid Bias	
at 180 volts	13.5 volts negative
" 135 "	9 " "
" 90 "	4 to 6.5 " "
Amplification Factor	8.2
Plate Impedance	
at 180 volts	9,400 ohms
" 135 "	10,000 "
" 90 " (-6 v. C)	11,300 "
Mutual Conductance	
at 180 volts	870 micromhos
" 135 "	820 "
" 90 " (-6 v. C)	725 "
Plate current	
at 180 volts	6 mils
" 135 "	5 "
" 90 " (-6 v. C)	3 "
Maximum Undistorted Output	
at 180 volts	0.140 watt
" 135 "	0.055 "
" 90 "	0.020 "
Base—Special five-prong type	
Mechanical dimension	
Maximum overall length	4-1/8 inches
" diameter	1-13/16 "

UX-226 or CX-326 Amplifier Tube
(A. C. Filament Type)

Filament voltage	1.5 volts A.C.
Filament current	1.05 amperes
Plate voltage—recommended	90-135 volts
maximum	180 volts
Grid Bias	
at 180 volts	13.5 volts negative
" 135 "	9-12 " "
" 90 "	6 " "
Amplication Factor	8.2
Plate Impedance	
at 180 volts	7,000 ohms
" 135 " (-9 v. C)	7,400 "
" 90 "	9,400 "
Mutual Conductance	
at 180 volts	1,170 micromhos
" 135 " (-9 v. C)	1,100 "
" 90 "	875 "
Plate current	
at 180 volts	7.5 mils
" 135 "	6 to 3 mils
" 90 "	3.7 mils

Continued on page 4, column 1

What Governs the Power Handling Capacity of an Amplifier

By A. R. WILSON, Engineering Department

As the novelty of radio has gradually disappeared, and more interest is taken in it purely as an instrument to reproduce with fidelity both music and speech, the listener and engineer have given more and more thought to the tonal qualities of the broadcast receiver. The vast radio audience today is first of all concerned in how **well** it can hear. How **far** is a secondary consideration.

It would seem to the average listener inexperienced in radio experimentation that all that is necessary to increase volume is the addition of a stage or two of audio frequency amplification to his existing equipment. This is true to a certain extent, but as we are interested only in *QUALITY VOLUME*, the design of the apparatus used in the "stage or two" of audio frequency amplification is of great importance.

A speaker, which does the actual reproducing of sound, is an energy operated device and as the energy is derived from the last audio tube alone, the undistorted volume obtainable from a speaker is wholly dependent upon the energy output of this tube and no other. The energy is measured in milliwatts and the following table gives the power output of the tubes now in common use, with the plate voltage necessary to obtain full output:

Tubes	Undistorted Output	Plate Voltage
UX 120	110	135
UX 226	160	180
UX 112	195	157
UX 171	700	180
UX 210	1500	425

In order to secure the maximum power output that a tube is capable of delivering, it is necessary that a sufficiently large voltage be placed on the grid of the tube to operate at its maximum output. At the same time certain conditions, however, must be satisfied to prevent distortion in the tube itself. First, the grid must not be allowed to become sufficiently positive to draw any appreciable amount of grid current, and second, the plate current must at no portion of the cycle be allowed to fall so low that distortion be caused by curvature of the plate current curve. The input voltage which may be applied safely to a tube without causing grid distortion is fairly well indicated by the grid bias voltage. Actually the effective grid swing permissible in volts R. M. S. is $\frac{\sqrt{2}}{2}$ or .707 times the grid bias.

The solution of the problem of *QUALITY VOLUME* is threefold, embracing tubes, transformers and speakers wherein distortion of various sorts and causes tends to develop. It may be well to state here that there are two apparent forms of distortion to guard against in any audio amplifier: frequency distortion and waveform distortion. Frequency distortion, which really is not distortion at all, but the relative differences in the amplification of different frequencies is caused by one of two things, either a coupling device that is not capable of even performance over the audio range, or the improper matching of impedances of the different circuits. It is extremely important from a frequency viewpoint that the impedances of the various circuits bear a definite relation to each other. To secure a maximum transfer of voltage from one circuit to another (and we are interested in this respect only in voltage and not in energy), the impedance of the transformer primary should be at least two or three times that of the tube circuit at the lowest frequency which we wish to amplify. Waveform distortion in the amplifier itself is caused by either an overloaded tube or saturation of the core of the audio transformers. With the present-day standards of transformers, however, the latter from a practical standpoint may be entirely disregarded. Obviously the remedy for an overloaded tube is the reduction of the input signal or the increase of grid bias and plate voltage, thus permitting the tube to be worked on the straight portion of its grid voltage plate current curve.

Assuming one to have an audio amplifier and tubes of the standards of two or three years ago, the most radical improvement in quality would be brought about by the replacement of the last audio tube by one of the new power tubes, such as the UX 171 or UX 210. This would increase the power handling capacity of the amplifier 50 to 100 times and this power handling capacity of an amplifier is something that is not very well understood by the average man, yet it is extremely important if faithful reproduction is to be obtained. In order to produce the same intensity to the ear, say at 60 cycles, many times as much power is required as at 1000 cycles. A somewhat disconnected yet fitting illustration would be the comparison between a Tuba player and a Cornet player in a brass band. The Tuba player expends much more energy, but to the ear the Cornet is louder. In the case of the loudspeaker far greater power is needed to supply the energy than was heretofore thought necessary to reproduce bass notes properly, and it is even very doubtful if the tubes on the market today are capable of supplying to the speaker enough energy to reproduce these low frequencies with the same intensity as the higher frequencies, unless a 50 or 100 watt power tube is used. This would require a type of plate supply device, which from an economic point of view, would be entirely out of the question.

While it would seem that increasing the energy output of an amplifier would result in extremely loud reproduction, this is not necessarily true. A loud sound may be doubled in intensity—that is, the energy doubled—and the ear may hardly detect the change. This fact will explain in some measure why many people are not able to note the difference in the volume produced by a UX 171 and UX 210 tube, although the maximum output of the UX 210 is double that of the 171. Everything else being equal, the reproduction, when using the UX 210, should appear much better on the lower frequencies—actually it is about the same, because the lower plate impedance of the 171 permits a greater transfer of energy from tube to speaker at these frequencies.

The power handling capacity of an amplifier using present day transformers is more or less limited by that of the tubes used, since the largest possible portion of the negative side of the grid voltage plate current curve is available for the actual plate voltage used. While resistance or straight impedance coupled amplifiers are better from a purely frequency standpoint, the power handling capacity is decidedly limited, as there is a certain rectifying action of a strong signal caused by the time action of the grid condenser and leak, and their purpose, even from a frequency standpoint, is often defeated by the improper use of tubes. A man will quite frequently pay from $10.00 to $20.00 for an impedance coupled amplifier only to use a 201-A tube in the last stage, and it is very doubtful if the improvement in quality in this case is even noticeable to the ear. This is only another example of insufficient power required to reproduce bass notes, although the frequency characteristic of an impedance or resistance coupled amplifier is essentially a straight line from 30 cycles upward. A very interesting laboratory experiment along these lines proved that where a pure 60 cycle note from a vacuum tube oscillator was fed directly into the grid of a UX 210 tube, the full output of this tube did not produce even an audible sound at this frequency. All low frequencies are not entirely lost, however, as their harmonics are reproduced, but with much less intensity, and the fundamental pitch is usually obtained by the beat note of a second and third harmonic.

In reviewing the subject of power handling capacity of an amplifier, there are many other more important phases to consider than the particular method of coupling (transformer, resistance, or impedance). It is a well-known fact that no better quality can be expected than is radiated from a broadcasting station or that can be faithfully reproduced by the loudspeaker — regardless of what coupling method or combination of methods may be used.

Bearing in mind that the frequency range of the better broadcasting stations is something like 80 cycles to 5000 cycles, and the better loudspeakers cut off at 80 cycles at the lower end and 7000 cycles at the upper end, also remembering that the better transformers in use today are capable of even amplification between 60 cycles and 6000 cycles, the selection of the amplifier tubes and proper operation for maximum efficiency of those tubes should receive more consideration than is generally given to amplifier tubes, particularly the last stage tube from which the loudspeaker is operated.

Data on New A. C. Tubes

Continued from page 2

Maximum Undistorted Output	
at 180 volts	0.160 watts
" 135 " (-9 v. C)	0.070 "
" 90 "	0.020 "
Base—Standard Large "UX" or "CX"	
Mechanical Dimensions	
Maximum overall length	4-11/16 inches
diameter	1-13/16 "

NOTICE

With each copy of the June issue of the Experimenter a postcard was mailed to be properly filled out and returned if future issues of the Experimenter were desired. So many cards have been returned that it has been impossible to revise our list before releasing the July issue. We are consequently sending the July issue to our complete list.

The August issue, however, will be mailed only to those who have returned postcards.

New General Radio Parts for A. C. Operation

TYPE 440A LOW VOLTAGE TRANSFORMER

The alternating current tubes require a source of low voltage capable of delivering large current. The various types of tubes require several different voltages. The Type 440A transformer supplies voltages for all popular tubes and sufficient current for all ordinary receiver requirements. Filament supply is provided for filament, separate heater, power and rectifier tubes.

The transformer will carry a total load of 70 watts. The actual current which may be drawn from any winding depends on the current being drawn from the other windings. The watts being drawn from any winding when supplying filaments may be found by multiplying together the current and voltage for the winding. The sum of these products for all the windings is the total load on the transformer. In a particular case the loads might be:

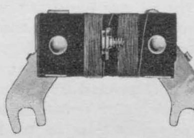
Volts	Amperes	Watts
2	10	20
3.5	5	17.5
5	2.5	12.5
7.5	2	15

TOTAL WATTS 65

Pri. 115 V (for lines 105-125 volts) 60 cycles.

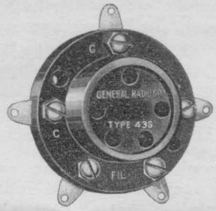
The Type 440A low voltage transformer sells for $10.

TYPE 439 CENTER TAP RESISTANCE



The new tubes for alternating current filament operation require a resistance with center tap across the filament. In the filament type of tube, the center tap provides the point of connection for the positive grid and negative plate potential sources. The Type 439 Resistance is designed to fit directly across the tube socket. No other mounting is necessary. Price, $.60.

TYPE 438 SOCKET



All of the new A. C. tubes, with the exception of the Type UY-227 or C-327 detector tubes, have the standard UX or CX four prong base and mount in the General Radio Type 349 Socket.

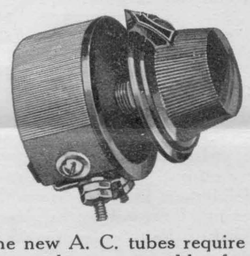
The new Type UY-227 or C-327 detector tube, however, has a separate heating element, and has consequently a five prong base which requires a socket especially designed with five spring contacts.

The Type 438 Socket is designed for the UY-227 or C-327 tube.

Firm contacts are made to the sides of the tube prongs with double gripping springs. The base of the socket is of moulded bakelite.

The Type 438 Socket sells for 50 cents.

TYPE 410 RHEOSTATS



The new A. C. tubes require low resistance rheostats capable of carrying appreciably more current than those used with D. C. tubes.

The resistance wire of the Type 410 Rheostat is of brass, tightly wound on a specially treated fibre strip. The form is of genuine moulded bakelite. The tapered knob, which is also of moulded bakelite, has an engraved pointer which indicates the position of the switch arm along the arc of the resistance unit.

The Type 410 Rheostat has the single hole mounting feature.

Resistance	Current	Price
.5 ohm	3.5 amperes	**$1.25**
1.5 ohm	2.0 amperes	**1.25**

The GENERAL RADIO EXPERIMENTER

VOL. 2 NO. 3 AUGUST, 1927

Further Data on New A. C. Tubes

By HORATIO W. LAMSON, Engineering Department

At the present time so much interest is centered around the new A.C. tubes that we believe further information concerning them will be of interest to our readers. We are indebted for much of the following data to an Engineering Bulletin recently issued by the E. T. Cunningham Laboratories.

In the July issue of the "Experimenter" we discussed the general principles of operation of two distinct types of A.C. tubes, namely: the —26 A.C. Filament Type (UX-226 or CX-326) and the —27 Separate Heater Type (UY-227 or C-327).

The —26 type of tube is designed for use as a radio or an audio amplifier and has the same characteristics as the UX-201A or CX-301A, except that the mutual conductance is somewhat higher. It is equipped with the standard UX four prong base and has an oxide-coated ribbon type of filament which is heated with "raw A.C." consuming, however, a larger current at a lower voltage than the D.C. tubes, i.e., 1.05 amperes at 1.5 volts A.C. (For detailed specifications of these tubes see the July issue of the "Experimenter.")

It has been found possible, by a careful choice of filament current and voltage ratings, to obtain a close balance between the electromagnetic and electrostatic fields set up within the tubes by the alternating current, thereby minimizing the so-called "grid effect" of the filament and other undesirable conditions. This balance is made to occur under the condition at which the tube operates most successfully as an amplifier.

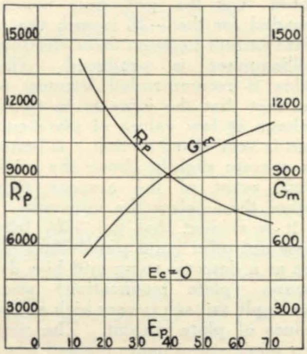


FIGURE 1

Figure 1 shows the plate impedance Rp and mutual conductance Gm of this tube plotted against the effective plate voltage Ep. It should be noted that the curve is drawn for the case of zero grid voltage, which, of course, is not the normal operating condition. The curve may be used, however, to obtain the ordinate values, corresponding to any magnitude of grid bias, by determining the "effective plate voltage" in each case, that is, by subtracting from the actual plate voltage the product obtained by multiplying the grid bias voltage by the amplification constant Mu of the tube. For example, if the tube is being used with 135 volts on the plate and with —12 volts grid bias, the effective plate voltage is [135—(12×8.2)] or 36.6 volts. Thereby we see from the curves that the plate resistance and mutual conductance are 9600 ohms and 870 micromhos respectively.

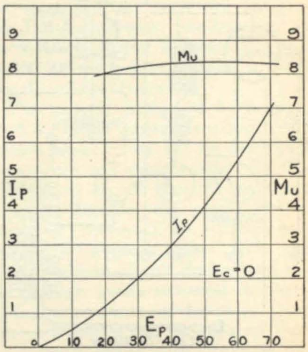


FIGURE 2

Figure 2 shows the plate current Ip and amplification constant Mu plotted against the effective plate voltage.

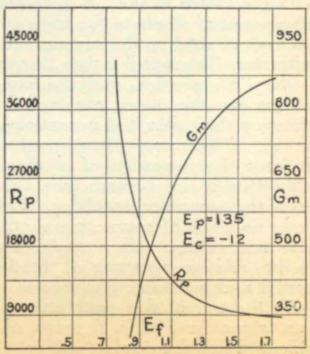


FIGURE 3

any modulation of the carrier is not appreciable unless the radio frequency stages are unstable and tend to oscillate. The radio frequency grid returns may be connected to the center tap of a resistance across the filaments as they do not require a critical adjustment. R. F. bypass condensers across this resistance are sometimes advisable.

The —27 is a tube of the indirectly heated type, having a cathode, or electron-emitting member, consisting of an oxide-coated metal cylinder in place of the usual filament. Inside of this cylinder, and insulated from it, is placed the heater filament which requires 1.75 amperes and 2.5 volts A.C. For this reason the tube cannot be operated in parallel from the transformer winding supplying the —26 tubes. Other considerations of circuit design likewise make it desirable to have a separate winding for this tube. The —27 is also similar in characteristics to the UX-201A or CX-301A, although it is slightly higher in mutual conductance and considerably lower in inter-electrode capacity. This tube is intended primarily as a detector used in conjunction with the —26 and is mounted on a special five-prong base. The —27 is particularly adapted to detector service because of its freedom from ripple voltage at low plate currents, which permits the use of either grid leak or grid bias detection. When detector sensitivity is not an important factor grid bias detection (plate rectification) may be used. A greater amount of audio amplification may be employed when using the —27 tube as a detector rather than any of the "raw A.C." types. Figures 9 and 10 show the variation of Rp, Gm, Ip, Mu, with respect to effective plate voltage in the case of the —27 type, while Figure 8 indicates its extreme freedom from ripple.

Since the —27 tube uses an indirectly heated cathode it takes longer for it to reach an operating temperature than is the case with tubes in

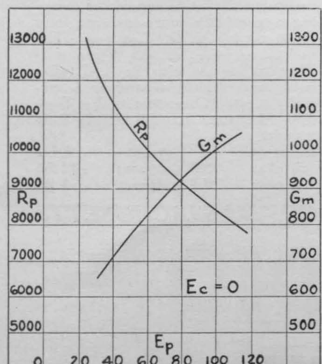


FIGURE 9

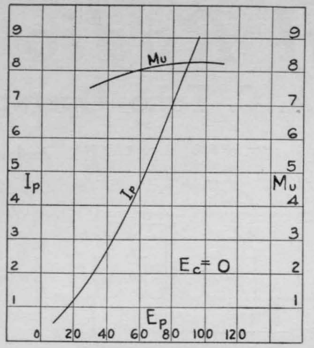


FIGURE 10

which the cathode is heated directly. The curve in Figure 11 shows that an average tube starts to operate at about twenty seconds and comes to normal operation at the end of thirty to forty seconds after the heating current is turned on.

To compete successfully with battery receivers it is essential that sets employing A.C. filament tubes com-

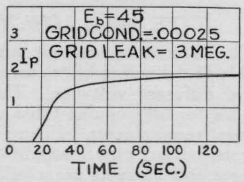


FIGURE 11

pare favorably with them in respect to all important operating characteristics, including tone quality, volume, sensitivity, selectivity, and freedom from hum, power line disturbances, and service troubles. The cost and weight of component parts is also an important consideration.

One of the most important requisites for obtaining true tone quality is the use of a tube in the last stage of the audio amplifier that is designed to handle the necessary power output without distortion. In this respect the Type UX-171 or CX-371 is strongly recommended. Used only in the last stage, the filament of this tube may be heated directly with "raw A.C." at the proper voltage and, with a center tap resistance for grid return and the proper bias and plate voltages, the operation will be about as satisfactory as if the filament were heated by a storage battery.

The sensitivity and selectivity of the radio frequency stages is essentially the same with the —26 tubes as with the —01A. The high mutual conductance of the —26 is partly offset by the necessity of using a grid bias, which is contrary to common practice in the use of the D.C. tubes. The sensitivity of the detector plays an important part in determining the overall sensitivity of the receiver. When the —27 type is used grid leak detection is practical so that equal detector sensitivity, as compared with battery operated receivers, is obtained.

With respect to freedom from hum, the —26 and —27 combination affords very satisfactory results if the proper precautions with respect to circuit design are followed. The ripple voltage given by each type, shown on the attached curves, is actually a combination of 60 cycle and 120 cycle components with a small amount of higher harmonics. A direct comparison under operating conditions shows that the amount of ripple voltage introduced by the A.C. filament supply is of the same order of intensity as that given by the better types of plate supply devices and is not audible more than a few inches from the loudspeaker.

To obtain freedom from line disturbances care must be taken to prevent the direct pick-up of such disturbances by the tubes and associated equipment. Power transformers should be shielded if placed in the same cabinet with the receiver and, under certain conditions, an electrostatic shield between the primary and secondary windings of the transformer is desirable.

The rugged design of both types of A.C. tubes insures freedom from service troubles as far as the tubes themselves are concerned. By the elimination of all devices requiring corrosive liquids, the possibility of corroded connections disappears and it is evident that, with the proper care in circuit design and the use of high grade material in parts, a greater measure of freedom from service troubles can be secured than has been possible with previous designs of radio receivers. Furthermore, the annoyance of storage battery attention or the trouble and expense of dry cell renewals is removed by the use of a receiver which draws all of its electrical power from a convenient house-lighting socket.

With respect to the cost and bulk of component parts, this A.C. tube combination is particularly satisfactory since the use of a heavy and expensive A filter system or A supply unit is avoided, for the necessary A voltages may be obtained merely by adding a few turns of wire to the power transformer supplying the plate supply unit or by the use of a small separate transformer designed for this purpose.

The combination of the —26 tubes as radio and audio amplifiers with the —27 as a detector, makes possible the same overall performance, tube for tube, as is obtainable with battery operated receivers.

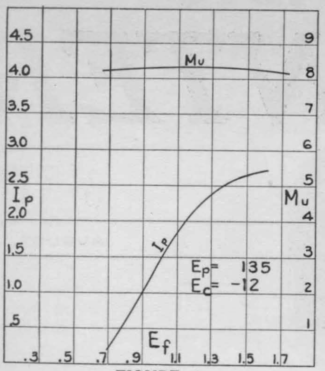


FIGURE 4

Figures 3 and 4 show the variation of Rp, Gm, Ip and Mu as the filament voltage Ef is varied. The flatness of the Rp curve from 1.3 to 1.7 volts on the filament indicates that the tube is relatively insensitive to voltage fluctuations over this range and hence is not bothered by variations in the supply line.

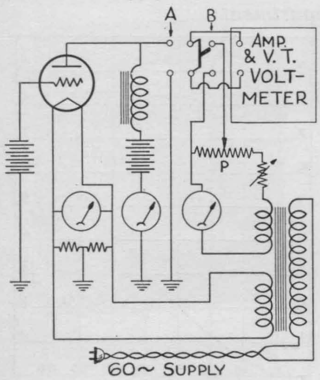


FIGURE 5

Figure 5 gives the circuit arrangement whereby the amount of "ripple voltage" in the plate circuit of a tube, heated with A. C., may be measured by comparison with a known voltage from the same source. With the switch in the "A" position the amount of ripple in the plate circuit may be read on the vacuum tube voltmeter. The switch is then thrown to the "B" position and the same reading on the meter obtained by adjusting the calibrated potentiometer P. This comparison method obviates the necessity of a direct calibration of the vacuum tube voltmeter and associated amplifier. Such a scheme gives, of course, merely the total hum voltage with no indication of the relative amounts of fundamental and harmonic frequencies.

By the use of this apparatus the data given in Figure 6 were obtained. Here the ripple (millivolts) existing in the plate circuit of the

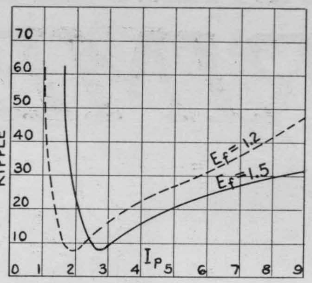


FIGURE 6

—26 tube at various values of plate current is shown. The values of plate current were chosen as abscissae instead of plate voltage in order to bring out the fact that minimum hum occurs at a plate current of about three milliamperes, the exact position varying only slightly with changes in grid voltage, but to a larger extent with changes in filament voltage as indicated in the dotted curve which shows the readings obtained when the filament voltage is reduced to 1.2. It will be noted that the grid bias recommended for the —26 is such that a plate current between three and four milliamperes is produced. This value is recommended because of the fact that the increase in ripple voltage at low values of plate current is very sharp so that it is better to operate slightly above the minimum point of the average tube rather than below the minimum.

It is evident that the —26 tube does not offer good possibilities for use as a detector using grid bias detection (plate rectification) since the ripple voltage is very high at low values of plate current. The very low minimum of hum obtained when the proper value of plate current is maintained results in an excellent performance of the tube when used as a radio frequency or audio frequency amplifier.

In Figure 7 the —26 tube is compared with Types CX-112 and CX-301A, the latter tubes being adjusted to their best operating point. A large reduction in ripple voltage, accomplished by the special filament design chosen for the —26, is clearly indicated in this figure.

It is essential for the correct operation of the —26 tube that the grid and plate returns (C+ and B—) be connected to the exact center or neutral point of the A.C. supply system, particularly when the tube is used as an audio frequency amplifier. The rapid rise in ripple voltage with departure from the correct balance point is shown in Figure 8.

To satisfy this condition the grid return may be attached to the center point of a resistance unit connected

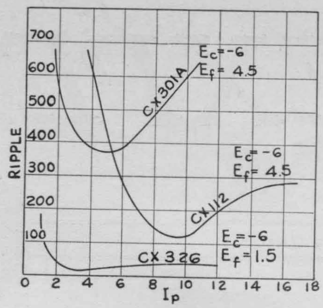


FIGURE 7

directly across the filament terminals. Under certain conditions it may be desirable to employ a low resistance potentiometer, affording thereby an adjustable center tap which will allow for the eccentricities of individual tubes or variation in the supply line balances.

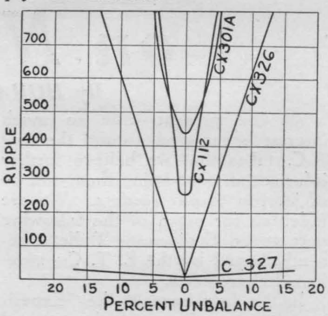


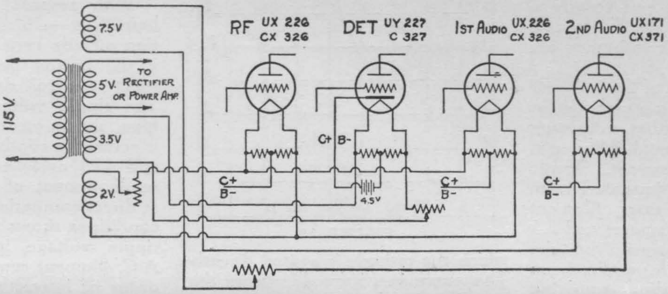
FIGURE 8

A comparison of the ripple voltage from four types of tubes is shown in Figure 8, the minimum for the CX-301A and CX-112 being slightly higher than in the previous figure since they were operated at five volts on the filament when taking these data. This curve shows the much lower minimum given by the —26 and also indicates that the grid return adjustment is less critical. We see that the grid return on the —27 type of tube is not at all critical because of the use of a separate heater element.

The —26 tube gives essentially the same performance as the UX-201A or CX-301A when used as a radio frequency amplifier since the inter-electrode capacity and other characteristics are practically identical. It is necessary in this case, however, to use a grid bias because, unlike storage battery tubes, operation without grid bias causes an uneven flow of grid current, resulting in a modulation and distortion of the incoming radio frequency signals, together with a marked decrease in amplification. When operated at the recommended grid bias, however, the ripple voltage is so low that

General Radio Parts

for A. C. Tube Operation



For the past several seasons the trend has been toward complete battery elimination. Many satisfactory plate supply units operating from A. C. have been developed, but filament operation from an A. C. source has presented more of a problem, due to the larger currents required and increased expense in the rectifier and filter circuit.

The newly announced A. C. tubes offer an excellent solution to this problem.

The above diagram shows how to adapt the filament wiring of the popular type of receiver to A. C. operation by use of General Radio parts especially designed for this purpose.

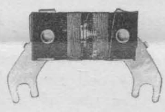
TYPE 440-A LOW VOLTAGE TRANSFORMER

The alternating current tubes require a source of low voltage capable of delivering large current. The various types of tubes require several different voltages. The Type 440-A Transformer supplies voltages for all popular tubes and sufficient current for all ordinary receiver requirements. Filament supply is provided for filament, separate heater, power amplifier and rectifier tubes. The following voltages and currents are available. Pri. 115 V (for lines 105-125 volts), 60 cycles:

Sec.	2 volts	10 amperes
	3.5 volts	5 amperes
	5 volts	2.5 amperes
	7.5 volts	2 amperes

Price $10.00

TYPE 439 RESISTANCE



The new tubes for alternating current operation require a resistance with center tap across the filament or heater. In the filament type of tube the center tap provides the point of connection for the positive grid and negative plate potential source. The Type 439 Resistance is designed to mount directly across the filament or heater terminal of any tube socket on which it may be used.

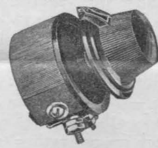
Price 60 cents

TYPE 438 SOCKET

All of the new A. C. tubes, with the exception of the Type UY-227 or C-327 detector tubes, have a standard UX or CX four prong base and mount in the General Radio Type 349 Socket. The new Type UY-227 or C-327 detector tube, however, has a separate heating element, and has consequently a five prong base which requires a socket especially designed with five prong contacts. The Type 438 Socket is designed for the UY-227 or C-327 tubes.

Price 50 cents

TYPE 410 RHEOSTATS



The new A. C. tubes require low resistance rheostats capable of carrying appreciably more current than those used with D. C. tubes. The resistance wire of the Type 410 Rheostat for use with the A. C. tubes is of brass, tightly wound on a specially treated fibre strip. The Type 410 Rheostat has the single hole mounting.

Resistance	Current	Price
.5 ohm	3.5 amperes	$1.25
1.5 ohm	2.0 amperes	1.25

GENERAL RADIO COMPANY : : CAMBRIDGE, MASSACHUSETTS

GENERAL RADIO

PARTS and ACCESSORIES

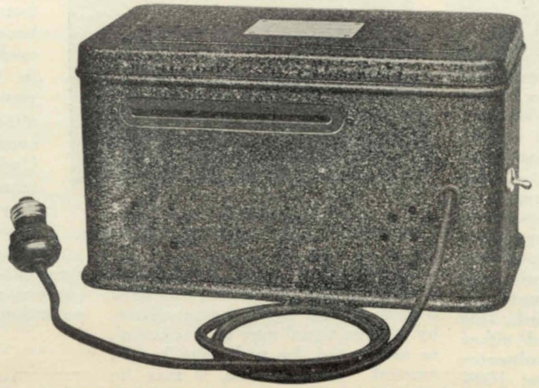
The GENERAL RADIO
EXPERIMENTER

VOL. 2 NO. 4 SEPTEMBER, 1927

Unique Method of Voltage Control Adapts Unit to Any Standard Type of Receiver

By P. K. McELROY, Engineering Department

The design of plate supply devices for the coming season has been sensibly affected by several factors which were not in existence a year ago, in addition to the ever-present desire to make improvements upon the product itself. Chief among these newer influences are the code of Fire Underwriters' rules just formulated and approved, the body of standards adopted by the Radio Manufacturers Association and the National Electrical Manufacturers Association, and the freedom or restrictions, depending upon the point of view, brought about by the Radio Corporation's enforcement of their patent rights and licensing of power unit manufacturers. All these considerations have had a bearing on the design of this season's plate supply unit, the Type 445.



THE NEW GENERAL RADIO TYPE 445 PLATE SUPPLY AND GRID BIASING UNIT

The standardization so much needed in the radio industry and simultaneously sought by committees of both the Radio Manufacturers Association and the National Electrical Manufacturers Association has caused two changes in design. The engraving on the binding posts now conforms to the similar recommendations of both committees. The B— terminal of the unit is no longer tied directly to the case, but connection is made through a 1 M.F. condenser to the case and the ground terminal. This protects the A battery from accidental short circuit with some battery connections, should the metallic case be pushed against a radiator or otherwise grounded (e.g., when B— and A+ are connected to one another, and A— is grounded).

The most important changes dictated by the Underwriters' Rules are for the purpose of protecting the user from the high voltages necessary to operate present-day power tubes at such a point as to give maximum audio output of true fidelity. While the voltages necessary for any but a 210 tube are too low to be dangerous, especially in a secondary circuit whose power output is so limited, they are high enough to be decidedly unpleasant when encountered unexpectedly. Accordingly, the binding post terminals have all been placed within the case. The connecting wires may be introduced through a slotted bakelite protecting panel parallel and adjacent to the binding posts. The slot is large enough to admit wires and terminals, but too small to allow the fingers to reach live parts. In order to afford protection when the case is opened, an automatic switch is inserted in the primary (110-volt) circuit in such a way that the circuit is made only when the cover is in place and is broken as soon as the cover is removed.

The new plate supply has been designed to use the UX-280 or CX-380 tube, which is capable of higher voltage and current output, better voltage regulation and longer life than the 213 type of tube. The voltage available under all but the most severe load conditions is sufficient to supply both maximum B and C voltages for a UX-171 or CX-371 tube.

Materials have been improved on account of the larger power supplied by the unit. The factor of safety for the paper condensers has been increased so as to obviate any danger of damage or inconvenience due to condenser puncture. The design of the choke coils in the filter has been improved so as to maintain the inductance at a high value to insure good filtering, even when a large current is being drawn from the unit so that the direct current flux tends to saturate the iron cores and decrease the inductance of the coils. The improvement can be noted from the fact that the ripple in the output of the new plate supply unit is considerably less at a larger current drain than the ripple from the old unit.

It was felt that no complication would be introduced by the addition of one C-voltage tap to supply bias for the power tube. This is of considerable value, since the C battery needed in that position is often almost as much as 45 volts. It was, however, necessary to conduct considerable investigation to determine the best arrangement of by-pass condensers in the output circuit, taking into consideration the amount and distribution of the ripple voltage and the fidelity of reproduction. As a result a circuit was developed which both keeps low the hum due to voltage ripple and makes very uniform the amplification at all audio frequencies.

The success which attended the use last year of fixed wire-wound resistances in the output voltage divider, a practice more generally followed by plate supply manufacturers this season, has prompted the retention of that method of voltage division. However, as it was desired to provide even closer voltage adjustment than was possible by the use of fixed taps on the output resistance, movable clamps have been provided for the C-voltage tap and for all B-voltage taps but the maximum. These clamps are not variable in the sense of variable resistances with knobs outside the case where they can be continually tampered with. The clamps may be moved back and forth, with the radio set in operation, until the correct positions are reached. This condition may be indicated either by using a high-resistance voltmeter with a resistance of at least 1000 ohms per volt or by ear in conjunction with the adjacent scale of approximate voltages. Each clamp is then fixed permanently in place by tightening the thumbscrew. With the tubes in use at present there is never any need to keep adjusting the plate voltages every few minutes, as one is tempted to do when there are control knobs outside the case. Line voltage variations seldom cause changes in output voltage sufficient to affect the set's performance. Accordingly, once the clamps have been set they need never be moved unless the plate supply is to power another set requiring different currents or voltages.

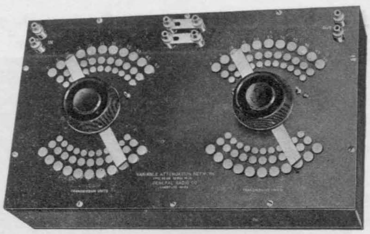
A further advantage of the clamps is that they permit a saving of output voltage taps, with a consequent lowering of price. While receiving sets rarely require over four different plate voltages, those four may be any of seven or more, namely, 22½, 45, 67½, 90, 135, 157½, 180, or choose your own. The price is materially reduced by replacing seven or more fixed voltage taps, which would inevitably vary slightly about their nominal values as current loads change, by four adjustable voltage taps, which can be set exactly as desired. Likewise, the single adjustable C-voltage tap takes the place of three or more fixed taps. When it is remembered that each tap must be bypassed by a condenser of at least 1 M.F. capacity, the saving is obvious.

The positive B-voltage taps provided are B+ DET, B+ AMP, B+ PWR1, and B+ PWR2, and the C-voltage tap is C— PWR. B+ DET supplies detector or intermediate frequency amplifier tubes, B+ AMP supplies radio, intermediate or audio amplifier tubes, B+ PWR1 supplies radio or audio amplifier or power tubes, and B+ PWR2 supplies power tubes. If it is preferred not to use on the power tube the full voltage available at B+ PWR2 any desired lesser voltage may be obtained at B+ PWR1 by adjusting the clamp. Grid bias for the power tube is obtained from C— PWR whether its plate is supplied from B+ PWR1 or B+ PWR2.

Type 445 unit is licensed by the Radio Corporation of America for radio amateur, experimental and broadcast reception only, and under terms of the R. C. A. license the unit may be sold only with tube. The price, including a UX-280 or CX-380 tube is $60.00

Design and Use of Attenuation Networks

By HORATIO W. LAMSON, Engineering Department



GENERAL RADIO TYPE 329
VARIABLE ATTENUATION NETWORK

In the laboratory devoted to communication engineering the need is often felt for an instrument whereby a given signal may be weakened, or attenuated, by a definite known amount. For instance, it may be convenient to measure one signal in terms of another by decreasing the louder until both are of the same intensity, a procedure frequently used in measuring the gain in amplifiers or the attenuation in line circuits.

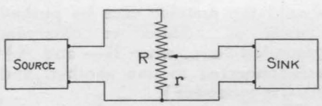


Fig. 1

One method of doing this is illustrated in Figure 1, which shows the familiar form of potentiometer. A fixed resistance, R, is connected across the terminals of the source, while a variable portion, r, of this resistance is connected across the sink into which the attenuated signal is fed. If this sink is a voltage-operated device, drawing no current, the potential at its input terminals will be equal to the output voltage of the source multiplied by the simple ratio $r/_R$. The impedance of the potentiometer, viewed from the source, will, of course, be equal to R, and should be made equal to the characteristic impedance of the source, viewed from its output terminals, if optimum working conditions are to be attained. Under these conditions the attenuation of the potentiometer may readily be calibrated in terms of T. U. (transmission units). If, however, the sink is a current-consuming device, then the expression for the attenuation of the potentiometer becomes more complicated, involving the characteristic impedance of the sink. Furthermore, the impedance of the potentiometer, viewed from either end, is a variable, changing with each setting of the adjustable contact. This will give rise to electrical reflections which will tend to produce wave distortion and kindred troubles.

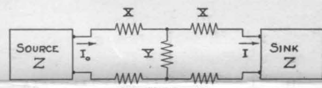


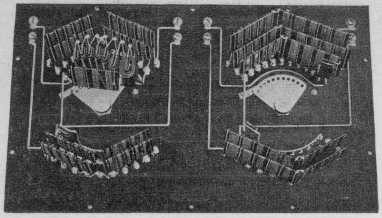
Fig. 2

If, however, we wish to produce a distortionless and easily computable attenuation between a source and sink, each having the same characteristic impedance Z, we may make use of the attenuation network shown in Figure 2. This so-called H-type network comprises four equal series resistances X, and an additional shunt resistance element Y, connected between the source and sink in the symmetrical manner indicated. If such a network is intended to introduce a definite number, N, of transmission units of attenuation, then, the values of X and Y may be computed from the equations:

$$X = \frac{Z}{2}\left(\frac{k-1}{k+1}\right)$$

$$Y = 2Z\left(\frac{k}{k^2-1}\right)$$

$$\text{where } k = \frac{I_o}{I} > 1$$



INSIDE VIEW OF TYPE 329 VARIABLE ATTENUATION NETWORK

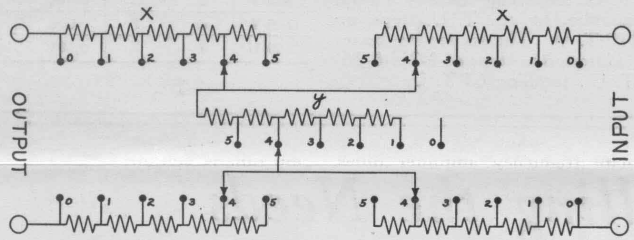


FIG. 3

the ratio of the current, Io, leaving the source to the current, I, entering the sink.

Expressed in terms of transmission units:

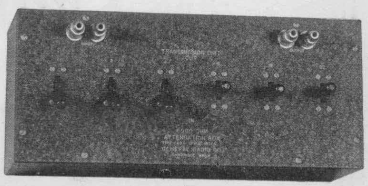
$$k = 10^{N/20} = \text{antilog}\ \frac{N}{20}$$

where N equals the number of T. U.'s attenuation.

A single such network offers, of course, a definite amount of attenuation determined by the values of X and Y. If, however, all five branches of the network are made adjustable by steps, as indicated schematically in Figure 3, and if the five switch arms are moved in unison to the corresponding switch points, then, by a proper calibration of the X and Y branches, the characteristic impedance Z of the network may be maintained constant while its attenuation is varied by any desired steps.

In certain lines of work it may be desirable to ground the center point of the Y shunt branch. This can be accomplished by using a network with six adjustable switch arms, as indicated in Figure 4, wherein the shunt resistance Y is bisected into two equal parts.

The General Radio Company has developed a series of attenuation networks operating on these principles. Each instrument, as shown in the illustrations, contains two decade H type networks which may be used individually or joined in series. In one series of these instruments the decades are calibrated in steps of 5 T. U. and 0.5 T. U. respectively, giving a total attenuation of 55 T. U.; while in the second series, the decades are calibrated in steps of 2 T. U. and 0.2 T. U., giving a total attenuation of 22 transmission units. These instruments may be obtained calibrated for a characteristic impedance of either 600 ohms or 6000 ohms, as desired. The table on the bottom of this page gives pertinent data.



GENERAL RADIO TYPE 249 ATTENUATION BOX

Instead of varying attenuation by the adjustment of the five branches of a single network section, as hithertofore described, the same results may be obtained by adding two or more fixed sections in series. The method of doing this, with H type sections, is illustrated in Figure 5. A four-pole double-throw switch serves to insert or remove each particular section at will. Given the characteristic impedance and the desired attenuation in Transmission Units of such a section, the necessary values of the X and Y branches may be computed directly from the previous equations.

In place of the symmetrical H-type network, it is frequently permissible to utilize the simpler but unbalanced T-type networks for attenuation purposes after the manner indicated in Figure 6. Here a double-pole double-throw switch suffices to throw each section into or out of circuit. The resistance values are calculated in the same manner, except that each of the two X branches has, obviously, the value 2X in order to maintain the same total series resistance in the network.

For certain types of experimental work an adjustable attenuation box having one T. U. as the smallest unit is sufficient. Accordingly the General Radio Company has devel-

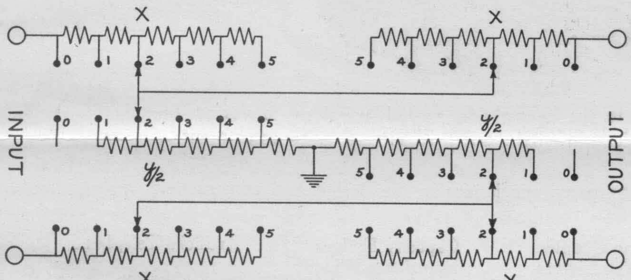


FIG. 4

TYPE	CHARACTERISTIC IMPEDANCE	TOTAL ATTENUATION	NET PRICE
329-H	600	55 TU	$220.00
329-J*	600	55 TU	$240.00
329-K	6000	55 TU	$235.00
329-L*	6000	55 TU	$255.00
329-M	600	22 TU	$230.00
329-N*	600	22 TU	$250.00
329-O	6000	22 TU	$240.00
329-P*	6000	22 TU	$260.00

The types marked * are provided with a center tap for the Y branch, as indicated in Figure 4. A limited number of certain of these types are carried in stock; others may be built to order.

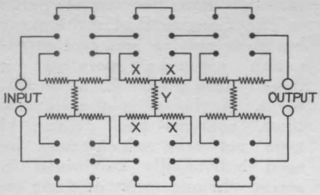


FIG. 5

oped a series of Type 249 Attenuation Boxes containing six or eight fixed sections which are controlled by individual switches. While this type does not permit as rapid manipulation as the Type 329 networks, it is, nevertheless, quite satisfactory. The illustration shows the appearance of one of these boxes.

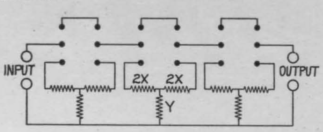


FIG. 6

The eight section boxes are calibrated in steps of 1-2-3-4-10-20-30-40 T. U., affording thereby a total attenuation, by one T. U. steps, up to 110 T. U. The six section boxes are calibrated in steps of 1-2-4-8-16-32 T. U., totalling 63 T. U.

The following types are built to order:

Type No.	No. of Sections	Type of Section	Characteristic Impedance	Price Net
249-A	6	H	600	$100
249-B	6	H	6,000	$110
349-C	6	T	600	$90
249-D	6	T	6,000	$100
249-H	8	H	600	$120
249-J	8	H	6,000	$150
249 T	8	T	600	$100
249-U	8	T	6,000	$130

The GENERAL RADIO EXPERIMENTER

VOL. 2 NO. 5 OCTOBER, 1927

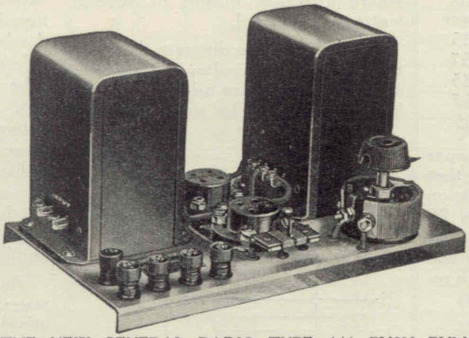
Power Amplification

By C. T. BURKE, Engineering Department

Unlike the grid circuit of a vacuum tube, a loudspeaker consumes a considerable amount of power. The action of the last stage in the audio amplifier is therefore different from that of any preceding stage.

In order to understand clearly the difference in the action of the last amplifier stage, it is necessary to consider load impedances in the several stages and the current delivered to them. When amplification per stage is spoken of, voltage amplification is usually meant. It is customary to speak of the vacuum tube amplifier as a purely voltage device. This is not strictly true in any stage and is far from the truth in the power stage. While the grid of the tube operates on voltage alone, the plate must deliver power. The objection to the specification of voltage amplification alone is evident when an amplifier feeding a load of 100,000 ohms is compared with one feeding a load of 2,500 ohms. It is proper to refer to voltage amplification alone, only when the load impedances are equal; otherwise the load impedances should be specified or a correction applied. When an output transformer is used, the voltage across the primary of the transformer rather than across the speaker should be considered as the output voltage on considering voltage amplification.

The power consumed in the stages of the amplifier prior to the last is not generally appreciable. While the current delivered by the secondary is negligible, exciting current and transformer losses must be supplied by the plate circuit of the preceding tube.



THE NEW GENERAL RADIO TYPE 441 PUSH PULL AMPLIFIER, A VERY EFFICIENT AND CONVENIENT UNIT TO USE IN BUILDING POWER AMPLIFICATION.

The power requirements of the speaker, however, are large. Some of the power delivered is lost in the speaker windings, but most of it is transformed into sound waves and radiated. Current is required to actuate the speaker, and modern speakers are comparatively low impedance devices. This requires an impedance adjusting transformer in the plate circuit of the last tube, which involves a considerable step-down in voltage. The last stage of the amplifier must be capable of delivering an amount of power to the speaker commensurate with the volume of sound desired without overloading the tube if quality is to be preserved. In order to meet this requirement, a power stage should precede the speaker.

It is perhaps necessary to distinguish between a power amplifier and a powerful amplifier. A power amplifier cannot be applied successfully directly after the detector; one or more stages of voltage amplification must precede it. The greater the power rating of the amplifier, the more the voltage amplification required to precede it, as a general rule.

Receiving set power amplifier tubes range all the way from the –20 type with an undistorted output of about 100 milliwatts to the –10 type with an undistorted output of about 1500 milliwatts. As each of these tubes differs as to input requirements, the choice of the power amplifier will depend on the rest of the amplifier. If sufficient signal voltage is not available to operate the power amplifier satisfactorily, nothing is gained by adding it. It is, therefore, necessary to consider the first part of the amplifier in designing the power stage.

Too great voltage amplification in the audio amplifier should not be attempted, as undue noise and an unstable amplifier is likely to result. The audio amplifier should not be depended on for distant reception; that is the function of the radio frequency system.

For satisfactory amplification the detector output should be one-tenth to five-tenths volts (across the primary of the first coupling unit). Signal strengths of less than the lower value should be increased by radio frequency amplification, those greater than one-half volt should be cut down by means of a volume control, otherwise the detector is overloaded. Obviously, the only proper place for the volume control is in front of the detector. Volume controls across the audio transformer secondaries, or the speaker, are poorly placed.

Assuming a signal of 0.2 volt, and a voltage amplification of 20 (one stage low-ratio transformer and tube) there is available for operating the power stage 4 volts. Assuming a 2 to 1 step-up for the input transformer to the power tube, 8 volts is available at the grid of the power tube. Tube data tables show the output under these conditions with various tubes to be as follows. Power is in milliwatts in each case. As the plate voltage available is generally limited, the plate voltage required is also given. If lower plate voltages are used the input must be reduced to avoid over-loading, and, as will be observed, this is an important factor in choosing the amplifier tube. This data is calculated from vacuum tube data tables and represents approximate average values.

Signal Voltage 8

Tube	Power Output	Plate Voltage
201A	50	135
120	15	67
112	120	135
171	28	67
210	65	135

Obviously the 112 is the proper tube to use. Suppose, however, that the input voltage and amplification ratio had been such as to give 25 volts at the power tube grid. As neither the 201A nor 112 tube can be used on this voltage the choice reduces to:

Signal Voltage 25

Tube	Power Output	Plate Voltage
120	110	135
171	350	135
210	950	350

In comparing the 171 and 210 tubes it should be noted that under these conditions the 210 requires a plate voltage of 350 as compared to 135 for the 171. In order to operate with 135 volts on the plate of the 210, the input voltage would have to be cut to 9 volts with the volume contol, when the output would become but 65 milliwatts.

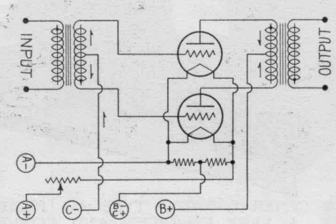
Increasing the input still further to 35 volts, only the 171 and 210 tubes may be used, the 171 giving 530 milliwatts output with 170 volts plate, and the 210 giving 1500 milliwatts with 425 volts plate. Again comparing the outputs for equal plate voltage, we find that the output of the 210 is only 140 milliwatts at 170 volts plate.

The 171 tube will take a maximum input of 40 volts with 180 volts plate, giving a 700 milliwatt output.

So far, only single power tubes have been considered. Where considerable power output is required, the push-pull connection, using two tubes in a single stage, offers many advantages even where the output desired is no greater than could be obtained with a single tube.

In the "push-pull" stage, two tubes are so connected that their power outputs add. Any type of tube may be used, the choice of tube depending on the same consideration outlined as applying to the single tube type. Thus the push-pull connection might be used with −12 type tubes when the input voltage is too low for operating a tube of the −71 type satisfactorily, but when greater power is required than is obtained from a single −12 type, −71 tubes might be used in order to obtain a greater power output than is possible with a single 210 without the high plate voltage needed for that type of tube, or 210 tubes might be used where a power output of several watts was required.

Referring to the diagram the large arrows show how voltages impressed across the input are added in phase in the output. The smaller arrows



show the course of voltages which are in phase in the grid circuits. These voltages cancel out and do not appear in the output. This fact is of great importance in the operation of the amplifier as it permits a greatly increased power output. Tube overloading, so long as grid current does not flow, is due to the amplifier working over a curved portion of its characteristics, introducing harmonics of the original frequency. As these harmonics are in phase, they cancel out and do not appear in the output. The working range of a tube is not limited to the straight portion of the characteristic when used in a push-pull amplifier. So greatly is the power output increased by this fact, that the maximum undistorted output from the push-pull amplifier is not twice but five to seven times that of a single tube. This feature is of particular importance when working into the low impedance load presented by most of the modern high quality loudspeakers, since the effect of a low impedance in the plate circuit is to increase the curvature of the tube characteristic, and lessen its capacity for undistorted power output.

If alternating current filament supply is used a further advantage of the push-pull connection appears, because hum voltages in the two tubes are in phase and therefore their fundamentals and odd harmonics cancel in the output. The result is a much quieter amplifier than is possible using a single tube.

For use with the Type 441 Push-Pull Amplifier, illustrated, the General Radio Company recommends the type −26 tubes. The maximum undistorted power output of the amplifier with these tubes is greater than a single type −71 tube, and the unit possesses the further advantage of quiet operation on alternating current supply, and a greater gain than is possible with a −71. Due to the latter fact the unit requires considerably less signal voltage on the tube grids to obtain maximum output. This in turn requires less gain between the detector and the power stage. If, however, the voltage amplifier has sufficient gain to deliver fifteen to twenty volts at the primary of the input transformer −71 type tubes can be used in the push-pull amplifier with excellent results.

As is usual when using a power stage, the gain in voltage is comparatively small, about 6 from the primary of the input transformer to the speaker terminals. The gain from the primary of the input transformer to the primary of the output transformer is about 20. It should be remembered, however, that very little power is delivered to the input transformer, while several hundred milliwatts are delivered to the speaker.

The input impedance of the type 441 unit is 30 henries. The turns ratio of the primary of the input transformer to the entire secondary is 1 to 4.5. There is a step down of about 3.5 to one in voltage in the output transformer to adapt the tubes to the speaker impedance. This gives the proper impedance ratio for −26 type tubes. When using the −71 type better results will be obtained if the speaker is connected between one plate terminal and the center of the primary of the output transformer. The resistance of the output transformer primary is so low that little direct current flows in the speaker under these conditions, and no stopping condenser is required.

Definition of the Transmission Unit

By Horatio W. Lamson, Engineering Department

The use of the Transmission Unit (TU) as the proverbial " yardstick" for measuring the gain or degree of amplification in amplifiers, the loss in any type of transmission circuit, or for comparing the strength of two signals, is becoming so universal that we believe a definition of this unit will be of interest to our readers.

Let us consider, for the sake of a concrete example, the case of the push-pull amplifier illustrated by the diagram in Mr. Burke's article in this issue. In order for this instrument to function, a certain amount of alternating current power, P1, measured, if you will, in milliwatts, must be supplied to the input terminals of the amplifier. There will be, in this case, a greater amount of power P2, likewise measured in milliwatts, delivered to the loudspeaker from the output terminals of the amplifier.

The quantity $\frac{P_2}{P_1}$ is called the "Power Ratio" of the amplifier. To express this power ratio in transmission units we make use of the relation:

$$\frac{P_2}{P_1} = 10^{\frac{n}{10}} \text{ or } N = 10 \log \frac{P_2}{P_1}$$

That is, the number of transmission units, N, is equal to ten times the logarithm (to the base 10) of the power ratio.

A conversion table is printed below giving the relation between transmission units and the power ratio gain or loss. From this we see, for example, that an amplifier has a gain of 7.0 TU when its power ratio is 5.01, or that there is a loss of 2.6 TU in a telephone line when the power ratio of the same is 0.550, etc.

For power ratios greater than 10 or less than 0.1, we may use the same table by following the proper one of the four procedures described below:

1—Divide the power ratio gain by ten and add ten to the corresponding number of TU.

2—Multiply the power ratio loss by ten and add ten to the corresponding number of TU.

3—Subtract ten from the number of TU gain and multiply the corresponding power ratio gain by ten.

4—Subtract ten from the number of TU loss and divide the power ratio loss by ten.

No. of T.U.	Power Ratio		No. of T.U.	Power Ratio		No. of T.U.	Power Ratio	
	Gain	Loss		Gain	Loss		Gain	Loss
0.1	1.023	.977	3.6	2.29	.437	7.1	5.13	.195
0.2	1.047	.955	3.7	2.34	.427	7.2	5.25	.191
0.3	1.072	.933	3.8	2.40	.417	7.3	5.37	.186
0.4	1.096	.912	3.9	2.45	.407	7.4	5.50	.182
0.5	1.122	.891	4.0	2.51	.398	7.5	5.62	.178
0.6	1.148	.871	4.1	2.57	.389	7.6	5.75	.174
0.7	1.175	.851	4.2	2.63	.380	7.7	5.89	.170
0.8	1.202	.832	4.3	2.69	.372	7.8	6.03	.166
0.9	1.230	.813	4.4	2.75	.363	7.9	6.17	.162
1.0	1.259	.794	4.5	2.82	.355	8.0	6.31	.158
1.1	1.288	.776	4.6	2.88	.347	8.1	6.45	.155
1.2	1.318	.759	4.7	2.95	.339	8.2	6.61	.151
1.3	1.349	.741	4.8	3.02	.331	8.3	6.76	.148
1.4	1.380	.724	4.9	3.09	.324	8.4	6.92	.144
1.5	1.413	.708	5.0	3.16	.316	8.5	7.08	.141
1.6	1.445	.692	5.1	3.24	.309	8.6	7.24	.138
1.7	1.479	.676	5.2	3.31	.302	8.7	7.41	.135
1.8	1.514	.661	5.3	3.39	.295	8.8	7.59	.132
1.9	1.549	.645	5.4	3.47	.288	8.9	7.76	.129
2.0	1.585	.631	5.5	3.55	.282	9.0	7.94	.126
2.1	1.622	.617	5.6	3.63	.275	9.1	8.13	.123
2.2	1.660	.603	5.7	3.72	.269	9.2	8.32	.120
2.3	1.698	.589	5.8	3.80	.263	9.3	8.51	.118
2.4	1.738	.575	5.9	3.89	.257	9.4	8.71	.115
2.5	1.778	.562	6.0	3.98	.251	9.5	8.91	.112
2.6	1.820	.550	6.1	4.07	.245	9.6	9.12	.110
2.7	1.862	.537	6.2	4.17	.240	9.7	9.33	.107
2.8	1.906	.525	6.3	4.27	.234	9.8	9.55	.105
2.9	1.950	.513	6.4	4.37	.229	9.9	9.77	.102
3.0	1.995	.501	6.5	4.47	.224	10.0	10.00	.100
3.1	2.04	.490	6.6	4.57	.219	20.0	100	.01
3.2	2.09	.479	6.7	4.68	.214	30.0	1,000	.001
3.3	2.14	.468	6.8	4.79	.209	40.0	10,000	.0001
3.4	2.19	.457	6.9	4.90	.204	50.0	100,000	.00001
3.5	2.24	.447	7.0	5.01	.200	60.0	1,000,000	.000001

VITAL FACTORS
in attaining
High Quality Reproduction

Type 285

High quality reproduction depends upon three things; correctly designed coupling units, proper use of amplifier tubes, and an efficient reproducing device.

For over a decade the subject of audio frequency amplification has been extensively studied in the laboratories of the General Radio Company with particular attention given to the design of coupling units.

As a result of this exhaustive research the General Radio Company has been, and is, the pioneer manufacturer of high quality Audio Transformers, Impedance Couplers, and Speaker Filters.

If the amplifier of your receiver is not bringing out the rich bass notes and the mellow high tones as well as those in the middle register why not rebuild your amplifier for ***Quality Reproduction*** with ***General Radio*** coupling units.

Type 373

TYPE 285 AUDIO TRANSFORMERS

These transformers give high and even amplification of all tones common to speech, instrumental, and vocal music. Available in two ratios.

Type 285-H Audio Transformer 1 to 6__Price $6.00

Type 285-D Audio Transformer 1 to 3__Price $6.00

TYPE 367 OUTPUT TRANSFORMER

This unit adapts the impedance of an audio amplifier to the input of any cone type speaker, thus promoting better tone quality and protecting the speaker windings against possible damage from A. C. voltages. Similar in appearance to the Type 285.

Type 367 Output Transformer__________Price $5.00

TYPE 373 DOUBLE IMPEDANCE COUPLER

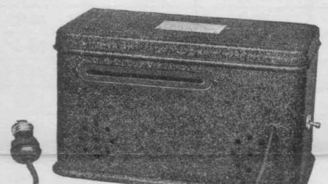
Many prefer the impedance coupling method of amplification to resistance coupling as lower plate voltages may be used and greater amplification may be obtained. The Type 373 is contained in a metal shell and connected in a circuit in precisely the same manner as a transformer.

Type 373 Double Impedance Coupler___Price $6.50

TYPE 387-A SPEAKER FILTER

The Type 387-A consists of an inductance choke with condenser. It offers a high impedance to audio frequency currents and forces these currents to pass through a condenser into the speaker, thereby improving tone quality and protecting the speaker windings.

Type 387-A Speaker Filter_____________Price $6.00

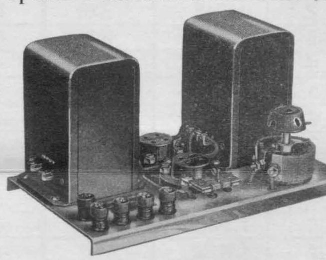


Type 445

Write for Series A of amplification booklets describing various amplifier units

—

General Radio Co.
Cambridge, Mass.



Type 441

TYPE 445 PLATE SUPPLY AND BIASING UNIT

The Type 445 meets the demand for a thoroughly dependable light socket plate supply and grid biasing unit that is readily adaptable to the tube requirements of any standard type receiver. Any combination of four voltages from 0 to 180 may be taken from the adjustable "B" voltage taps. A variable grid bias voltage from 0 to 50 is also available. The unit is designed for use on 105 to 125 volt (50 to 60 cycle) A. C. lines and uses the UX-280 or CX-380 rectifier tube.

Licensed by R. C. A. and through terms of the license may be sold with tube only.

Type 445 Plate Supply and Grid Biasing Unit ____________________________Price $55.00

Type UX-280 or CX-380 Rectifier Tube Price $ 5.00

TYPE 441 PUSH-PULL AMPLIFIER

The Type 441 is completely wired and consists of two high quality push-pull transformers, with necessary sockets and resistances mounted on a nickel finished metal base board. It may be used with any power or semi-power tube to increase the undistorted output of the amplifier with the result that better quality is reproduced from the loudspeaker with more volume than is obtained from other methods of coupling.

Licensed by the R. C. A. and through terms of the license may be sold with tubes only.

Type 441 Push-Pull Amplifier_________Price $20.00

Type UX-226 or CX-326 Amplifier Tube, Price 3.00

Type UX-171 or CX-371 Amplifier Tube, Price 4.50

GENERAL RADIO

PARTS and ACCESSORIES

The GENERAL RADIO EXPERIMENTER

VOL. 2 NO. 6

NOVEMBER, 1927

The General Radio Experimenter is published each month for the purpose of supplying information of particular interest pertaining to radio apparatus design and application not commonly found in the popular style of radio magazine.

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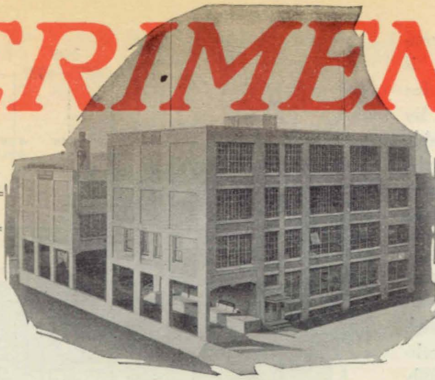


An A. C. Operated Amplifier with a High Quality Power Output

By A. R. WILSON, Service Department

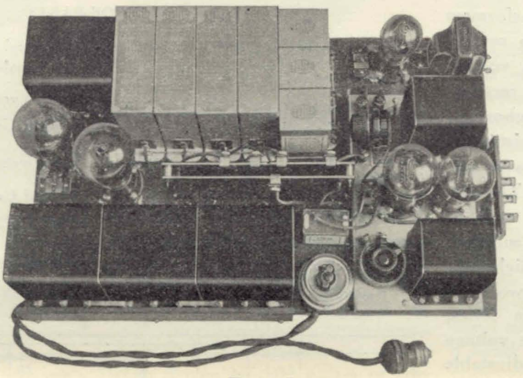


Figure 1
THE GENERAL RADIO A C POWER PACK

For those people who demand the most perfect reproduction obtainable, a power amplifier is a necessity. A power amplifier is not intended primarily to increase the volume of a set but rather to make use of amplifying tubes capable of many hundred times the power delivery of the ordinary 201-A Type. When a large amount of energy is delivered to the speaker, low notes and overtones, which heretofore have been either inaudible or distorted, are heard with a fidelity that is really remarkable.

Now we are concerned, prior to the input of the last tube, in securing a voltage amplification gain, but at the end of the amplifier we have a device, our loudspeaker, which requires real physical energy to operate it satisfactorily; hence, the power tube.

The introduction of the UX-210 power tube has meant much in the advancement of quality reproduction and when this type of tube is used in a push-pull system, which has the advantage of minimizing or eliminating most of the harmonic distortion caused by the tubes themselves, the reproduction becomes almost perfect. The push-pull system also has the advantage of increasing the power output four or five times. To a certain extent, the greater the power output the better the quality. An unusual fortissimo passage finds the tube handling it with ease, like the hill climbing ability of a high powered motor car. There is enough energy to give the bass notes color and intensity with some to spare.

Why all this power? Let us draw an analogy. Today there is less and less opportunity of driving fast on the public highways and yet greater power is a feature of all motor cars. It is much more comfortable to drive a seventy mile-an-hour car at thirty-five miles an hour than to drive a fifty mile-an-hour car at the same speed. It is the flexibility, the sense of reserve, which makes the more powerful car desirable. This applies to radio. With the 210 type of tube the reader is literally loafing along, even when strong volume is being used.

The General Radio power pack is a complete two stage A. C. operated amplifier, adaptable for use after the output of the detector tube or with a phonograph magnetic pick-up, utilizing transformers with a UX-226 tube in the first stage and two UX-210 tubes in the last stage. The rectifier system has been designed to furnish approximately 750 volts DC when two UX-281 rectifying tubes are employed.

The voltages placed on the plates of the two UX-210 tubes have been made adjustable over a wide range as it was felt that the common practice of connecting the plate of the last stage tube directly to the high voltage side of the rectifying system was not in keeping with the maximum efficiency. In similar devices the grid voltage for the last tube is usually obtained by the voltage drop through a resistance placed in the grid return. This resistance is usually variable and any adjustment of it affects the plate voltage, consequently the final adjustment is more or less an arbitrary value for both grid and plate voltages. By making the plate voltage variable over a wide range, it permits the tubes to be operated at their maximum efficiency regardless of the load.

The direct current available from the rectifying system is approximately 200 milliamperes. A high current output makes for better voltage regulation and will easily supply sufficient current to operate a multi-tube set with a great reserve of power.

The construction and placement of parts in the General Radio power pack is evident from Figure 1. The 110-volt supply from the house lighting mains is fed into the transformers which step the voltage up several hundred times. This high voltage alternating current is then rectified by two UX-281 rectifying tubes and passed through a filter consisting of one Type 366 choke, two 4 mf. and one 2 mf. condensers. The output is pure direct current such as could be obtained from a sufficient supply of B batteries. This high voltage is then passed through two Type 446 resistors connected in series, which makes any desirable voltage available by means of adjustable sliders. The last stage amplifier, is the General Radio Type 441 Push-Pull Amplifier. This consists of two transformers, sockets, and all necessary parts, completely wired and mounted on a metal baseboard. This simplifies construction somewhat as it eliminates quite a bit of wiring.

The wiring is all straightforward and simple. The only precaution needed is to place some sort of guard over the high voltage side of the power transformer and to use rubber covered wire for all connections. Under no circumstances should anyone attempt to make any adjustments without first turning off the electric current.

(*Continued on page 4, column 2*)

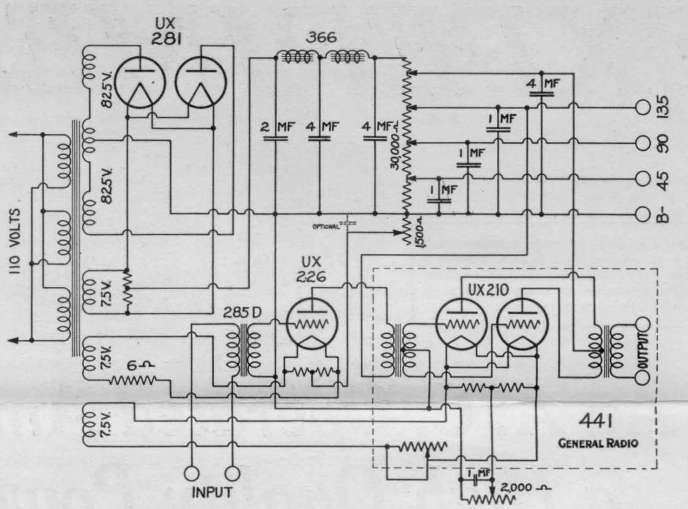


Figure 2
Schematic Wiring Diagram of AC Power Pack

LIST OF PARTS

3 General Radio Type 365 Transformers.

1 General Radio Type 366 Choke.

1 General Radio Type 441 Push-Pull Amplifier (completely wired).

2 General Radio Type 446 Resistance Units.

1 General Radio Type 285 D Transformer.

3 General Radio Type 349 Sockets.

2 General Radio Type 439 Centre Tapped Resistance Units.

1 General Radio 6 Ohm Resistance Strip capable of carrying one Ampere.

1 2000-volt 2mfd. Condenser.

3 1000-volt 4mfd. Condensers.

3 500-volt 1 mfd. Condensers.

1 1mfd Condenser.

1 Variable Resistance 2000 ohms.

1 Baseboard 12 x 20.

Misc. wire screws, bolts, etc.

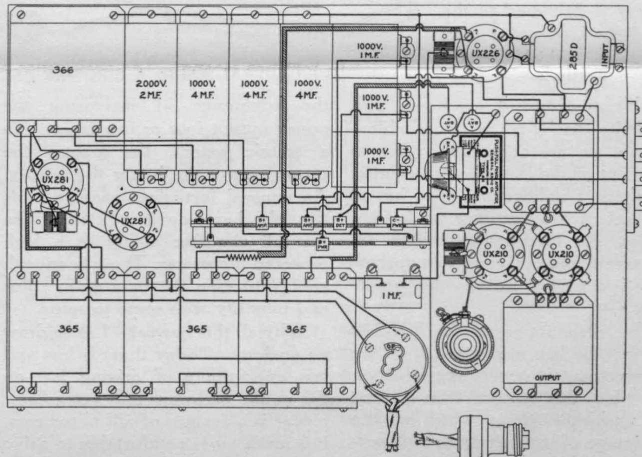


Figure 3
Pictorial Diagram of the General Radio Power Pack

THE SYNCHRONOMETER

By H. W. LAMSON, Engineering Department

THE SYNCHRONOMETER WITH THE TYPE 467 SYNCHRONOUS DRIVING FORK

An example of the special equipment which the General Radio laboratories are developing from time to time is to be found in the recently perfected Type 473 Synchronometer.

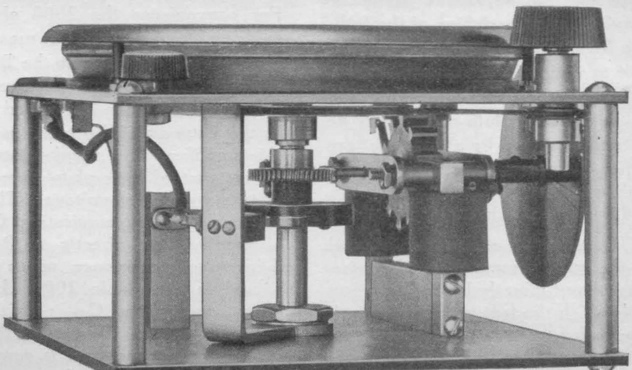
This machine is nothing more than an accurately timed automatic transmitting key which, in the model shown in the illustrations, is designed to close a pair of electrical contacts for a brief interval once in every five seconds. It has, however, a special feature in that, while the duration of contact can be adjusted at will to any value between .05 seconds and .50 seconds, the beginning of the contact interval, or in other words, the "nose" of the signal, always occurs exactly at the zero point on the scale.

The complete outfit comprises two instruments: the Synchronometer proper and the synchronous driving fork. (Type 467).

The Synchronometer carries a black bakelite dial, the circumference of which is graduated into one-second intervals, each second being, in turn, subdivided into twenty spaces. A clock hand, painted white for clear visibility, sweeps over this dial, keeping exact time when the proper adjustments have been made. The shaft carrying this hand is driven at a uniform speed by a small synchronous motor coupled to the shaft through a 50:1 reduction worm drive. The interior view shows the motor and the driving mechanism. The motor has two poles and a ten-tooth rotor, and hence a synchronous speed of 600 revolutions per minute when driven by 100 pulses of current per second. The extremities of the two field coils terminate in a pair of jacks on the upper panel of the instrument.

An insulating disc bearing an annular metallic segment is mounted upon the vertical shaft carrying the clock arm. Two spring contacts press radially against this segment. One of these is mounted in a fixed position which determines the "nose" of the signal. The second brush is mounted upon an arm which may be swung a certain angular distance around the shaft as a center. This brush determines the instant at which the circuit between both brushes through the revolving segment is interrupted and, hence, the duration of the interval of contact. In the front left hand corner of the upper panel will be seen a thumb screw for swinging this arm and clamping it in any desired position. The two brushes are connected to a second pair of jacks mounted upon the top panel whereby this time interval key may be connected into any desired circuit.

A second identical clock hand, known as the index hand, is mounted directly beneath the motor-driven hand. This index hand, which is normally stationary, is carried by a hollow shaft upon which is mounted, directly beneath the panel, a large grooved pulley. In the front right hand corner of the panel is located a hand knob which carries a small pulley beneath the panel. A belt of twine joins these two pulleys. Thus, by manipulating this knob, the index



DETAIL VIEW OF TYPE 473 SYNCHRONOMETER

hand may be set at any desired position on the scale.

The purpose of the index hand is as follows:—Suppose that the automatic signal, transmitted at zero time on the scale, sets in motion a train of mechanisms which, at some later time, produces a second signal, preferably audible in nature. The operator, by setting the index hand under the position of the revolving hand at the instant of the retarded signal, can obviously determine the time required for the operation of the mechanism. If this operation can be repeated a few times at five second intervals, a close determination of the elapsed time may be made. Various applications of a device of this sort will suggest themselves to the experimenter. Obviously a slight change in the design of the instrument will permit considerable variation in the time interval between signals.

The interrupted direct current of 100 pulses per second necessary for driving the synchronous motor is supplied by a 100-cycle electrically driven tuning fork. This is mounted in a separate cabinet which carries also ten No. 6 dry cells furnishing six volts for energizing the magnet of the fork and nine volts for operating the motor. Milliammeters are provided for measuring these two currents and a rheostat for controlling the current to the fork magnet. The fork draws about 20 milliamperes and the motor about 200 milliamperes. An adjustable contact is provided upon each tine of the fork, one for interrupting the magnet current to maintain the fork vibrations and the other for controlling the motor current. Both circuits may be opened or closed by a single battery switch. A twin conductor cord fitted with a plug on the synchronometer end joins the two instruments.

The accuracy of the time interval of the synchronometer is, of course, determined directly by the precision with which the frequency of the fork is adjusted to 100 cycles per second. Small changes in fork frequency can be made by manipulating the rheostat in the driving circuit, while greater changes are accomplished by the adjustment of two counterweights mounted near the outer extremities of the fork tines. A check upon this timing can, of course, be made by comparing the synchronometer with a stop watch. However, if accurately regulated 60 cycle lighting current is available the following procedure is simpler and more rapid. The shaft of the motor protrudes through the right hand side of the cabinet and carries a disc painted black with 12 narrow white segments uniformly spaced around it. When this disc is illuminated by a lighting source supplied with 60 cycle alternating current the spoked pattern will appear stationary if the speed of the motor is exactly 600 R.P.M. If the pattern, on the other hand, appears to advance in the direction of disc rotation, the speed of the motor, and hence the frequency of the fork, is too high and vice versa.

A small knurled handle is attached outside of this disc. This is twirled between the thumb and forefinger to start the motor, which may readily be brought up to synchronous speed by observing the disc pattern in 60-cycle light or by watching the pulses of the needle on the milliammeter reading the motor current.

Equipment of this sort is made to special order. Our engineering staff will be glad to consult with any of our readers who have need of such apparatus.

(Continued from page 2, column 1)

For convenience the 2000 ohm variable resistor is mounted by means of a metal bracket directly to the B— Binding Post of the Type 441 Push-Pull Amplifier. When AC is used to light the filament of the tubes used in this amplifier it is a simple matter to utilize part of their plate current to obtain a grid bias voltage. This is accomplished by connecting the C— Binding Post directly to B— and inserting a resistance, which in this case is a variable 2000 ohm resistor between the C— and the B— Binding Posts. By passing this resistance by a condenser is sometimes helpful in reducing hum.

The filament of the Rectifier tubes together with those of the Amplifier tubes are lighted from the low voltage secondaries of the type 365 Transformers. In the case of the UX-226 tube a fixed resistance of 6 ohms capable of carrying at least 1 ampere is inserted in one of the filament leads underneath the baseboard.

To operate this device it is simply necessary to connect the output of the detector tube or a phonograph magnetic pick-up to the primary of the type 285 D Transformer. The reproducer is connected to the terminals marked output on the type 441 Push-pull Amplifier. If it is desired, the push-pull stage alone may be used by connecting the output of another amplifier directly to the input terminals of the push-pull amplifier.

Under normal operating conditions the tubes, especially the 2UX-281 rectifying tube and the 2UX-210 together with the resistance unit, should get decidedly warm. If the plate of the 2UX-210 Amplifying tube should get red after a period of use it is an indication that the grid bias voltage used is improper and the biasing resistance should be adjusted until this condition disappears. It is almost a positive indication that one or more filter condensers are defective if the plate of the rectifier tube turns red.

Under operating conditions, with the primary of the type 285 D Transformer open, a hum should be heard in the reproducer. This, however, should almost disappear when the two input terminals are shortened or a reasonable load placed on them. In an AC operated device of this sort it is extremely important that the plate and grid voltages of the amplifying tubes be adjusted properly as this helps materially in reducing hum; also the cases of the various parts should be grounded to B—. When using a phonograph magnetic pick-up with this device it is sometimes helpful in removing needle scratch to shunt the input terminals by a fixed condenser. The proper value can only be determined after experimentation, but will usually be around .01 mfd.

The GENERAL RADIO EXPERIMENTER

VOL. 2 NO. 7

DECEMBER, 1927

The General Radio Experimenter is published each month for the purpose of supplying information of particular interest pertaining to radio apparatus design and application not commonly found in the popular style of radio magazine.

There is no subscription fee connected with the General Radio "Experimenter." To have your name included in our mailing list to receive future copies, simply address a request to the GENERAL RADIO CO., Cambridge, Mass.

DR. HULL JOINS OUR STAFF

An agreement has been made with the Radio Frequency Laboratories of Boonton, New Jersey, whereby on certain problems the facilities of each laboratory will be available to the other. The most important part of the plan, however, is that Dr. Lewis M. Hull will become Director of Research of both organizations, making his headquarters at our laboratories, here at Cambridge.

Dr. Hull is well known in the radio field and particularly for his active participation in the discussion of papers presented before the New York meetings of the Institute of Radio Engineers. He received his doctor's degree from Harvard University, where he specialized in physics, particularly in radio problems, under the direction of Dr. Pierce. He has taught at the University of Kansas, and was associated for four years with the Bureau of Standards in the capacities of consultant physicist, and then associate physicist. Since the founding of the Radio Frequency Laboratories nearly six years ago, Dr. Hull has been a member of the organization.

Factors Governing the Choice of Power Tubes

By C. T. BURKE, Engineering Department

The proper selection of tubes is of primary importance in the efficient design of an amplifier, that is, in obtaining an amplifier which gives the desired results at least cost, yet the frequent appearance of amplifiers in which a wiser selection would have resulted in a better or more economical amplifier bears testimony to lack of consideration of the factors involved.

Before considering the characteristics of the various tubes it is helpful to review the voltage and power relations in vacuum tubes in general. The following considerations apply to all types of tubes. In Fig. 1 the plate circuit of the tube is shown.

The voltage μE_g appears across the plate circuit as a result of the impressed grid voltage E_g and the amplification factor μ. R_P represents the internal plate impedance of the tube. R_L represents the load in the plate circuit, i. e., the input impedance of a coupling unit or reproducer. R_L is in most cases a reactance rather than a resistance, but it is convenient to consider it as a resistance, and no serious inaccuracies are introduced.

The following relations follow from the laws of electrical circuits.

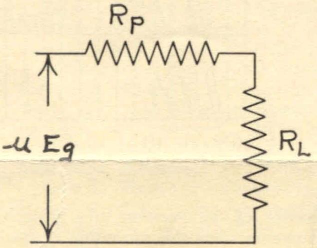


FIG. 1

Plate current (alternating) $I_P = \dfrac{\mu E_g}{R_P + R_L}$ (1)

Voltage across $R_L = \mu E_g$ — (2)

$$\frac{\mu E_g R_P}{R_P + R_L} = \mu E_g \frac{R_L}{R_P + R_L}$$

Power produced in $R_L =$ (3)

$$\frac{\mu E_g R_L}{R_P + R_L} \times \frac{\mu E_g}{R_P + R_L} = \frac{\mu^2 E_g{}^2 R_L}{(R_P + R_L)^2}$$

These equations are fundamental for all vacuum tubes, assuming the tube to be acting on the straight portion of its characteristic, i. e., that plate and grid voltages are properly adjusted.

Since the voltage across R_L is the useful output voltage of the tube, equation (2) summarizes the behavior of the tube as an amplifier. The voltage amplification of the tube and coupling device is seen to depend on three things, the amplification factor of the tube (μ), the plate impedance (R_P) and the load impedance (R_L). Increasing or R_L increases the amplification while increasing R_P reduces amplification The natural conclusion is that a tube with a high μ, low plate impedance and a high load impedance will achieve ideal results. Unfortunately, however, perhaps due to a particularly regrettable oversight on the part of the inventor of the device, amplification factor and plate impedance are not independently variable, but are so tied together in the design of the tube that changes tending to raise the amplification factor also increase the plate impedance. Furthermore, practical considerations limit the impedance of the load. If a resistance coupling device is used, the voltage drop in the resistor limits its value, and cost is a limiting factor when using other forms of coupling devices. The equation does show, however, the desirability of high input impedances in the coupling device. In practical tube design, a compromise is made between amplification factor and plate impedance, resulting in several classes of tubes for different purposes, i. e., the "high mu" type where a high load impedance is used, the "general purpose" for the conventional types of amplifier, and the power tubes which work into a low load impedance. Substitution of values in the equation shows that despite its low amplification factor, a tube having an amplification of 3 and a plate impedance of 2000 will have a greater amplification per stage when feeding a load of 2000 ohms than will a tube having an amplification factor of 8 and a plate impedance of 10,000 ohms. An important fact to remember.

The voltage equation will also answer the question frequently asked, may a "high mu" tube be used with coupling impedances designed for use with general purpose tubes. Suppose a "high mu" tube is used with a low value of coupling impedance, e. g.

$\mu = 30$, $R_P = 15{,}000$, $R_L = 30{,}000$

Voltage across $R_L =$

$$E_g \frac{30 \times 30{,}000}{180{,}000} = 5.0\, E_g$$

Compare with $\mu = 8.4$,
$R_P = 10{,}000$, $R_L = 30{,}000$

Voltage across $R_L =$

$$E_g\, 8.4 \;\frac{30{,}000}{40{,}000} = 6.3\, E_g$$

The answer is evidently, that under these conditions, the amplification per stage is less than with a "general purpose" tube, if the "high mu" tube is used.

Considering now the power equation, it can be seen that the power also is increased by increasing the amplification factor. As has been pointed out, however, this cannot be done without changes in the load impedance. It may be shown readily that the power output is a maximum when the plate and load impedances are equal. Thus the equation for maximum power output becomes

$$P\,Max = \frac{\mu^2 E_g^{\,2}}{4\,R_P} \qquad (4)$$

Comparison of the power and voltage equations reveals the fact that the same load impedance is not favorable both for obtaining a large voltage amplification and for obtaining a large power output. Thus it is seen that the fundamental distinction between a "voltage" and a "power" amplifier is in the load impedance connected in the plate circuit of the tube. In the interstage coupling device, a large increase of voltage per stage is desirable since the output of the last stage is governed primarily by the voltage impressed on its grid. The power required from the plate circuit of the interstage tubes is small, only sufficient to supply losses in the coupling device. Even with a coupling device of as high impedance as is practicable, the tube supplies sufficient power for these losses.

Equation (4) represents the maximum power that may be obtained from an amplifier tube. The behavior of the vacuum tube is such, however, that the operating characteristics are somewhat affected by the load impedance, a low impedance shortening the straight portion of the characteristic. This occurs, and distortion is introduced if a load impedance as low as the plate impedance of the tube is used. It has been experimentally determined that the maximum UNDISTORTED output of the tube is obtained when the load impedance is equal to about twice the plate impedance of the tube. Substituting these values in equation (3) we get,

$$P\,(\text{max. undis.}) = \frac{2\,\mu^2 E_g^{\,2}}{9\,R_P}$$

which is very little less than the maximum power of equation (4).

The result is in watts if Eg is the root mean square value of the signal voltage applied to the grid. It is generally more convenient to consider the peak value of the signal voltage, since this is limited to a value approximately equal to the grid bias voltage if tube overloading is to be avoided.

Then

$$P\ \text{max. undis.} = \frac{\mu^2 E_g^{\,2}}{9\,R_P}$$

where Eg is the PEAK signal voltage applied to the grid.

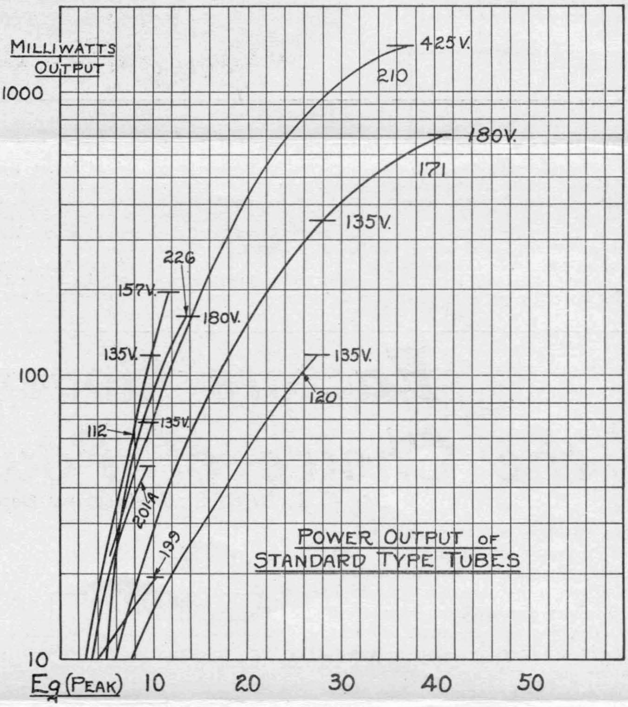


Fig. 2

We are now in a position to judge from the characteristics of the different types of tubes as to the best choice for a given use.

The power equation may be readily extended to include special output combinations, i. e., tubes in parallel and in "push pull" connection.

For the parallel connection, μ is unchanged, but Rp is reduced to half

Then

$$P\ \text{max. undis.} = \frac{2\,\mu^2 E_g^{\,2}}{9\,R_P}$$

Rp=plate impedance of one tube, or the output for any applied grid voltage up to the maximum permitted by the bias voltage is doubled. The allowable maximum signal voltage is not increased, and the load impedance must be halved.

This may be accomplished with a suitable output coupling device.

We are now in possession of the facts necessary for the proper design of the amplifier, saving excess material and expense as well as preventing bottle necks which limit the capacity of the amplifier at some points.

Three factors are to be considered in designing the amplifier-voltage input at the detector, power output desired, and the power supply available. The importance of the last factor is often overlooked, resulting in the common use of tubes at too low a plate voltage.

Fig. 2 shows the variation of power output with grid voltage (peak) of the standard amplifier tubes. In the vacuum tube data table on page 4 is shown the plate voltage required to maintain emission at the grid voltages specified. It is assumed that a peak signal voltage equal to the grid bias voltage may be used. This is not strictly true, the maximum allowable grid peak voltage being slightly less than the bias voltage. It will be further assumed that the amplification per stage is 0.9 μ times the transformer ratio. This relation is approximately correct, provided the coupling device has been properly designed.

It will be seen from the curves of Fig. 2 that when considerable loudspeaker power is required, the power stage cannot operate directly out of the detector. In order to obtain a power output in excess of 10 milliwatts, with any tube, a signal voltage of about 3 is required. The signal voltage in the detector plate circuit is usually 0.1 to 0.5 volts. We will assume 0.3 is an average value in the rest of this discussion. The importance of input voltage is apparent. The importance of the power supply as a limiting factor in the choice of tubes will be demonstrated presently.

Examination of the curves of Fig. 2 shows that at low input voltages the power outputs are bunched closely together. On the basis of the power required for 10 milliwats output, the tubes range as follows, 112, WD11, 210, 201A, 199, 226, 171 and 120. Up to 10 volts input, the 112 is superior to all other types. In comparing the output of the 210 with that of other tubes, it must be borne in mind that a high plate voltage is required for this tube. The output of the 210 at 180 volts plate is but 145 milliwatts.

The use of the curves can best be demonstrated by discussing a few typical cases.

Case 1.

Receiver—1 stage audio 201A tube 1:2.7 transformer—to add a power stage—no restrictions on power supply. There is available at the primary of the transformer a signal voltage of 0.3 x 0.9 x 8 x 2.7 (following the assumptions stated) =5.8

(a) input turns ratio to second stage 1:2.7; Eg=12. Inspection of the curves show that a 112 tube will be overloaded at this signal voltage. The 112 tube is so much superior to other types at low input voltages, however, that a greater power output will be obtained if the signal is reduced sufficiently to avoid overloading the 112 than if any other type of tube is substituted.

(b) input turns ratio 1:5.95; Eg=35

The 210 would be chosen in this case. If the plate supply voltage had been limited, the 171, or perhaps two 171's in parallel or push-pull would be used.

Case 2. Battery operated receiver.

3-volt filament—135 volts plate 1st. stage 1:2.7 transformer

Voltage at primary of second stage

0.3 x 0.9 x 6 x 2.7=4.4

Voltage on tube grid (6:1 transformers) 26 volts.

The battery requirements limits the selection to the 120 tube which would be overloaded, requiring either a reduction in signal voltage or the use of a lower transformer ratio.

Suppose it is desired to operate a separate power stage, with A. C. filament supply permitting the use of a 5-volt tube. If there is no limit to the plate voltage, a 210 would be used. This is another case where the parallel or push-pull connection could be used to advantage, to avoid high plate voltage.

Case 3. Receiver—detector only. It is desired to design an amplifier to supply the full output of a 210 type tube.

The curve shows the grid swing required to be 35 volts.

Assuming 0.3 volts in the detector plate:

$$\text{Required gain} = \frac{35}{.3} = 117$$

(between detector and the grid of the power tube).

Examine the following possibilities.

1. 1:2.7 transformer—201A—1:2.7 transformer; gain=53
2. 1:2.7 transformer—201A—1:6 transformer; gain=118
3. Double impedance—201A—Double impedance—201A—Double impedance; gain=49
4. Double impedance—201A—Double impedance—201A—1:2.7 transformer; gain=147
5. Double impedance—201A—Double impedance—201A—6:1 transformer; gain=330

It is apparent that neither the arrangement 1, nor 3 would be satisfactory. Arrangement No. 2 would just "get by," but would not be desirable as it permits no factor of safety. Arrangement No. 4 would be satisfactory, but some might prefer No. 5 which could be worked with lower signal voltages in the detector.

New General Radio Apparatus

TYPE 446 VOLTAGE DIVIDER

The experimenter or home set builder who is building a plate supply unit requires an adjustable resistance, in order to get the correct plate voltages for the several tubes in his receiving set. In the construction of the General Radio Type 445 Plate Supply Unit, a similar requirement existed, and to meet it, a separate wire wound resistance card with four adjustable sliders was developed. There have been so many requests to supply this card separately that we are now prepared to release it under the title of Type 446 Voltage Divider. The list price is $4.00.

The unit is wound in two sections, the larger section having a resistance of 15,000 ohms, and being provided with three adjustable sliders. This section is used for the plate supply. The second section has a resistance of 1500 ohms, and is provided with a single adjustable slider. This section is used for C biasing. The card, while rugged, is thin so as to keep inductance effects at a minimum. Convenient mounting brackets are provided.

ADJUSTABLE CENTER TAP RESISTANCE

While a resistance to go across the filament of the alternating current tubes usually requires a tap at its exact center, conditions often arise, due to unbalancing, when it is desirable to have the tap slightly off center.

To meet this condition, we have developed a center tap resistance similar to the Type 439, except that the tap is made by means of an adjustable slider. This enables the tap to be placed at the neutral point, thus reducing hum to a minimum.

This new unit, listing for 75c, and designated as Type 437, is now available for distribution.

VACUUM TUBE DATA TABLE

TYPE	FILAMENT VOLTS	FILAMENT AMPS.	B VOLTS	C VOLTS	PLATE CURRENT MILS	PLATE IMP. OHMS	MUT. COND. M.MHOS	AMP. FACTOR	PEAK EMISSION MILS.	OUTPUT MILLIWATTS UNDIST.	OUTPUT MILLIWATTS AS OSC.	CAPACITY COLD M.M.F.	MAX. DIA. INCHES	MAX. HEIGHT INCHES
WD 11	1.1	.25	22	0	.4	22000	260	6	25		6			
WD 12			45	-1.5	1.1	18000	345	6.2			30	G-F 6		
CX 11			67	-3	1.8	17000	365	6.2			85	G-P 5.5		
CX 12			90	-4.5	2.6	16000	390	6.2		12	150	P-F 7.5	1 7/16"	4 7/16"
$2.50														
UX 199	3.3	.063	22	0	4	26000	230	5.9	9		6			
CX 199			45	-1.5	1	19500	320	6.25			30	G-F 3.6		
UV 199			67	-3	1.7	16500	380	6.25			80	G-P 3.5		
CV 199			90	-4.5	2.5	15000	415	6.25		7.5	150	P-F 4.5	1 1/16"	3 1/2"
			135											
			90	-7.5	1.3	19000	330	6.25		15	80			
$2.25														
UX 120	3.3	.130	22	0	1	10000	320	3.2	24		16	G-F 4.5		
CX 120			45	4	2	8500	390	3.3			60	G-P 5.4		
			67	9	3	8000	410	3.3			140	P-F 4.4	1 3/16"	4 1/8"
			90	16.5	3.2	7700	430	3.3			200			
			135	22.5	7	6600	500	3.3		105	650			
			135	27	5.5	7500	430	3.2		110	500			
$2.50														
UX 201 A	5	.25	22	0	.5	26000	325	8.4	45		8	G-F 5.8		
			45	1.5	.9	18500	460	8.4			28	G-P 10.1		
			67	3	1.5	14000	600	8.4			70	P-F 6.1	1 13/16"	4 11/16"
			90	4.5	2	12000	710	8.5		15	130			
			135	9	2.5	11000	775	8.5		50	230			
			180	13	3	9000	940	8.5						
$2.00														
UX 112	5	.5	22	0	1.1	14500	550	8	150		17			
			45									G-F 9		
			67									G-P 11	1 13/16"	4 11/16"
			90	-6	2.4	8800	890	7.9		40	150	P-F 7.5		
			135	-9	6	5000	1640	8.2		120	550			
			157	-10.5	8	4800	1700	8.2		195	850			
$4.50														
UX 171	5	.5	22	0	4	3500	850	3	80		60			
			45	-5	6							G-F 6.8		
			67	-12	7						320	G-P 9.5	1 13/16"	4 11/16"
			90	-16.5	11	2500	1200	3		110	680	P-F 6.5		
			135	-27	16	2200	1320	2.9		350	1500			
			180	-405	20	2100	1380	2.9		700	2500			
$4.50														
UX 210	6	1.1	90	-4.5	3	9700	775	7.5	500	18	240	G-F 7		
			135	-9	5	8000	940	7.5		64	600	G-P 8		
			180	-10	7	7000	1070	7.5		145	1100	P-F 7		
	7.5	1.25	250	-18	12	5600	1340	7.5		340	2700		2 3/16"	5 5/8"
			350	-25	18	5100	1460	7.6		950	5500			
			425	-35	20	5000	1540	7.7		1500	7500			
$9.00														
UX 222 (RADIO)	3.3	.132	135	1.5	1.5	850,000	350	300					1 13/16"	5 3/8"
UX-222 (AUDIO)	3.3	.132	180	1.5	.3	150,000	400	60					1 13/16"	5 3/8"
UX 200A	5	.25	22		1.2	35000	570	20						
			45		1.5	30000	670	20					1 13/16"	4 11/16"
$4.00														
N (215 A)	1	.25										G-F 4.4 G-P 4.2 P-F 3.8	5/8"	2 1/2"
			67	-6	1	20000	300	6		8	40			
V (102 D)	2	.97											2 3/8"	4 1/2"
			130	-1.5	.75	60000	500	30		4.2	50			
L (216 A)	5-6	1											2 3/8"	4 1/2"
			130	-9	8	6000	980	5.9		60	600			
E (205 D)	4.5	1.6											2 3/8"	4 1/2"
			350	-22.5	33	3500	2000	7		890	8000			
UX 226	1.5	1.05	90	6	3.5	9400	875	8.2		20				
			135	9	6	7400	1100	8.2		70			1 13/16"	4 11/16"
			180	13.5	7.5	7000	1170	8.2		160				
UY 227	2.5	1.75	45		2	10,000	800	8						
			90		7	8 000	1000	8					1 13/16"	4 11/16"
UX 240	5.0	.25	135	1.5	.2	150,000	200	.30						
			180	3	.2	150,000	200	30					1 13/16"	4 11/16"
UX 280	FULL-WAVE RECTIFIER					FIL. TERM. VOLTS 5 V. FIL. CURRENT 2 A. A.C. PLATE VOLTS 300 V. (MAX. PER PLATE) R.M.S.			MAX. D.C. OUTPUT CURRENT BOTH PLATES 125 M.A.				2 3/16"	5 5/8"
UX 281	HALF-WAVE RECTIFIER					FIL. TERM. VOLTS 7.5 V. FIL. CURRENT 1.25 A. A.C. PLATE VOLTS 750 V. (MAXIMUM) R.M.S.			D.C. OUTPUT CURRENT RECOMENDED 65 M.A. MAXIMUM 110 M.A.				2 7/16"	6 1/4"

Note: Except for half ampere filament, UX-112 and UX-171 characteristics are