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RADIO CLUB OF AMERICA

Methods of Measuring Tube Characteristics

A Paper Delivered Before the Radio Club of America on February 17, 1927

By Keith Henney

Director, Radio Broadcast Magazine Laboratory

The Theory and Application of the Constant-Coupled Non-Reactive Plate Circuit Radio-Frequency Amplifier

A Paper Delivered Before the Radio Club of America on October 20, 1926

By Edward H. Loftin and S. Young White

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Methods of Measuring Tube Characteristics

A Paper Delivered Before the Radio Club of America Discussing the Several Bridge and D. C. Systems for Use in Obtaining Tube Characteristics

By KEITH HENNEY

Director, Radio Broadcast Laboratory

IT IS neither the desire nor purpose of the writer to burden this article with an eulogy on the vacuum tube. Nearly every article that has appeared on the tube in the popular radio press has done that, pointing out that it is a most wonderful device, the modern Aladdin's Lamp, and a number of other superlatives that fill up space. There can be no doubt that the tube is important. Witness our present broadcasting structure, our long-distance telephone service, our communication by telephone across the Atlantic, and by high frequencies and exceedingly low powers to all parts of the world. All of these things depend upon the tube.

No study of the tube can be complete without a knowledge of its varied services. For example, it is possible with a tube to convert direct current from a set of batteries to alternating current of all frequencies from as near zero as one likes up to 60,000 or more kilocycles. It is then possible, with another tube exactly similar to the first, to convert these extremely high frequencies back to direct current. It is also possible to amplify both direct and alternating currents, and hence amplify power. It is also possible to separate what is placed on the input of the tube into direct and alternating currents of practically any ratio desired. All of these varied functions are carried out without any moving parts, without noise, with practically no loss of power, and with so little fuss that tubes now exist that are capable of giving service for 20,000 hours, a life greater than that of the circuit in which they are used. There can be no doubt about the importance of the tube in the field of electrical engineering. In addition, tubes and their associated circuits are now being used to measure the rate of growth of plants, to measure extremely small differences of thickness, the strength and rapidity of a man's pulse, and from this latter, to determine whether he is a lover, a thief, a liar. The tube has been harnessed and trained to do a vast number of interesting tricks.

Now this little assembly of glass and metal performs its multitudinous functions with the aid of three elements. The first and most important of these elements is the filament. This filament has undergone rather remarkable changes since tubes first came into existence. The first ones were made of tungsten which operated with a high temperature, then going to low temperature oxide-coated filaments manufactured by a complicated and difficult process, thence to our most recent filament, the thoriated wire. The measure of efficiency of the filament is its emission per watt expended in heating it, and the newest thoriated wire is exceedingly efficient. Pure tungsten filaments operate at a very high temperature. Oxide filaments consume considerable current at low voltage and at a much lower temperature. Thoriated filaments are somewhere between.

The other two elements are the grid and plate, and because these elements can be changed in size and relative position, tubes differ in characteristics. There must, then, be some means by which engineers can compare tubes just as they rate generators and motors or other electrical apparatus.

TUBE CONSTANTS

IN TUBE engineering, there are two very important factors which, when known, define the tube in exactly the same manner that we used to say in school that the United States is bounded on the north by Canada, on the east by the Atlantic Ocean, etc. The two constants—which really are not constants at all—are the amplification factor and the plate impedance, and every function that the tube performs and its efficiency in doing so may be discovered by a knowledge of these factors and the constants of the circuits into which the tube works.

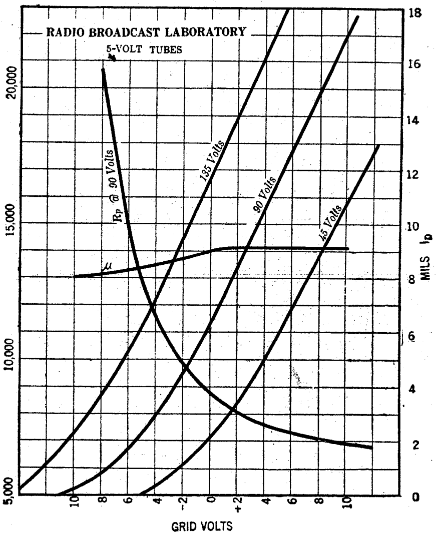


FIG. I

Another factor is the mutual conductance which, contrary to popular opinion, is not so important as it may seem. The term is somewhat difficult to picture physically. It has the dimensions of a conductance, *i.e.*, a current divided by a voltage, but the current exists in one circuit and the voltage in another, with the tube as the connecting link. It is due to Professor Hazeltine.

These constants, or factors, are variable within rather wide limits. For example, the amplification factor may range from 3 to 30, while the impedance varies, as someone has said, from Hell to Peru. The amplification factor is pretty well determined when the tube is sealed and pumped; that is, it depends to within very narrow limits upon the geometry of the tube. The mesh of the grid and its spacing with respect to the other elements are the governing factors. At low grid voltages the amplification factor falls off somewhat, rising to a maximum at zero grid voltage, and remaining constant thereafter, or falling gently in some tubes.

The plate impedance depends upon a lot of things, the filament efficiency, the amplification constant, and the grid and plate voltages. No one curve or graph can show how it varies. To properly represent it would require a three-dimensional model, such as has been constructed by Doctor Chaffee and others. Some photographs of very beautiful models of this nature may be seen in the *Proceedings of the I. R. E.*

After the tube is sealed and placed in operation the impedance changes with each change in instantaneous plate or grid voltage—all of which makes the theory of the tube more or less complicated.

These three elements, the filament, the grid, and the plate, cause any current flowing in the plate circuit to change, making it go through very wide fluctuations. The plate current is defined by the equation:

$$I_p = f\,(E_p + \mu E_g)$$

By maintaining constant any one of the three variables in this equation and varying the other two, we arrive at the relation between the plate current and the voltage on the grid or plate that we usually know as characteristic curves, and it is by means of these curves that the important tube factors are defined. For example, both grid and plate potential have some effect on the grid voltage, but the grid is relatively more important than the plate. In Fig. 1 it may be seen that at zero grid bias, changing the plate voltage from 90 to 135 changes the plate current by 5.2 milliamperes, while changing the grid bias by 5 volts will do the same thing.

The amplification factor is then defined as the ratio of the change in plate potential to the change in grid potential which produces the same effect in plate current. In this case the amplification factor is 9:

$$\mu = \frac{\Delta E_p}{\Delta E_g} = \frac{135-90}{5-0} = \frac{45}{5} = 9$$

The other factor of importance, the plate impedance, is the ratio between the change in plate voltage to the resultant change in plate current. In this case it is 45 volts divided by 0.0052 amperes, or roughly 8700 ohms:

$$R_p = \frac{\Delta E_p}{\Delta I_p} = \frac{135-90}{0.0116-0.0064} = \frac{45}{0.0052} = 8700$$

Now, as has been indicated by the Greek letter Δ in the definitions, these factors are defined by changes, and for accuracy the changes must be small.

The mutual conductance, defined as the ratio between a change in plate current and the change in grid voltage that produced it, is also the ratio between the amplification factor and the plate impedance, as can be seen from the mathematics below. For comparing tubes under exactly the same conditions, this factor is somewhat import-

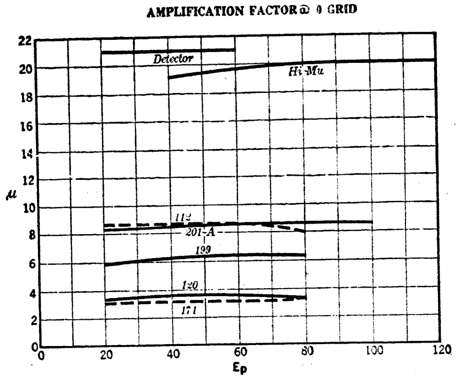


FIG. 2

ant, but as will be shown later, it serves little purpose in telling an engineer how well such a tube will function in the circuit:

$$G_m = \frac{\Delta I_p}{\Delta E_g} = \frac{\mu}{R_p} = \frac{\Delta E_p}{\Delta E_g} \div \frac{\Delta E_p}{\Delta I_p}$$

Figs. 2, 3, and 4 show how the tube factors change. The fact that the plate impedance is the reciprocal of the slope of the E_p–I_p curve is shown in Fig. 4. When the plate-current curve straightens out, the R_p curve is parallel to the E_p axis, but finally rises again as the saturation point is reached. These data were taken on a rather poor 199 tube.

It is a simple matter to get the tube factors from a set of characteristic curves which may show the effect upon the plate current of the grid or plate voltage. It is somewhat tedious, however, to take a mass of data and to plot it and then to pick off points on the resulting curves to determine the tube's factors. In actual practice it is simpler to go through a little routine, say of measuring the plate current under certain conditions of plate and grid voltage and then to get a new current by changing the grid voltage. This gives the mutual conductance. Then the plate voltage can be changed to get the plate impedance, and to multiply these factors together to get the amplification factor. At the risk of too much repetition the writer wishes to emphasize here that changes in grid and plate voltage must be small if the resultant determinations of amplification factor and plate impedance are to be representative of the tube's characteristics.

MEASURING THE TUBE CONSTANTS

THE various bridge methods of measuring tubes were developed to provide quick and simple means of measuring tubes.

MILLER D.C. BRIDGE

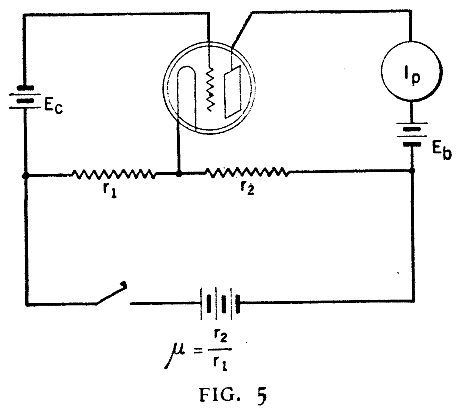


FIG. 5

One of the first methods of making quick measurements was due to J. M. Miller, and is shown in Fig. 5. In practice, the resistances, r_1 and r_2, are varied until closing the switch causes no change in plate current. Under these conditions the amplification factor is given by the ratio of r_2 and r_1. This follows from a consideration of the law governing the plate current as a function of grid and plate voltages given above.

If, with the switch closed, the voltage across plate and filament is increased, the corresponding grid-filament voltage is decreased. If no change in plate current takes place, however, the following relation holds:

$$(\Delta E_p + \mu \Delta E_g) = 0$$

whence $Ir_2 + \mu Ir_1 = 0$

and $\mu = \frac{r_2}{r_1}$

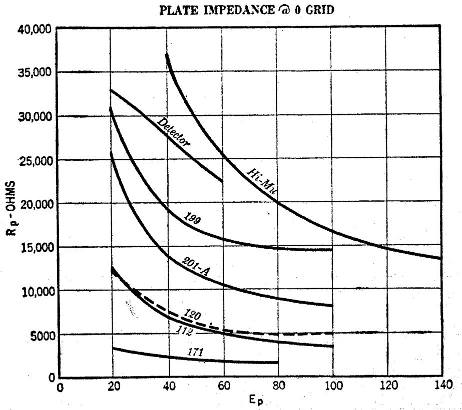


FIG. 3

LABORATORY BRIDGE

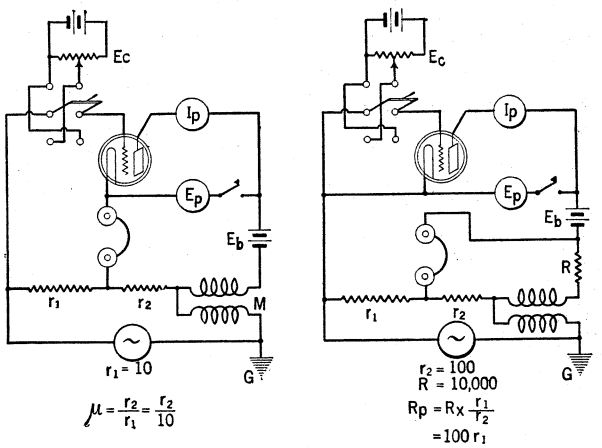


FIG. 7

The first improvement on this simple bridge was to substitute a.c. voltages and to use a pair of telephones in place of the plate ammeter. Under these conditions the amplification factor is found in exactly the same manner. When the bridge is balanced, indicated by silence in the receivers, the amplification factor is the ratio indicated above.

Miller described also the simple addition to this scheme which permits measurements of the plate impedance to be made as shown in Fig. 6. It is not difficult to prove that the bridge balance indicates that the following relation holds:

$$R_p = R\left(\mu \frac{r_1}{r_2} - 1\right)$$

There is one disadvantage in this system. It is necessary to measure the amplification factor before the other factor may be obtained. Since the amplification factor is a constant over the ordinary ranges of grid and plate voltages, one determination will suffice for a given tube. It must be remembered, however, that any error in measuring mu will cause an error in Rp.

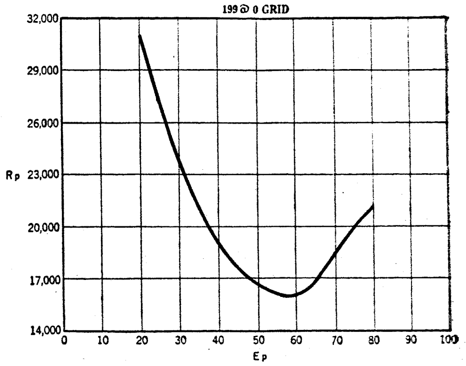


FIG. 4

In the Radio Broadcast Laboratory a bridge has been in use for several years which will measure either the mu or plate impedance, independently of each other, and has the additional advantage that the desired factors may be read directly. This bridge in its two forms, which are easily convertible to each other, is shown in Fig. 7. The method of obtaining the amplification factor is exactly that of the Miller bridge while the other constant is measured in another arrangement of the same parts used by Miller.

In all of these bridges it is necessary to use some amplification to indicate a balance unless the work is done in a quiet room. The amplifier should preferably use batteries separate from those used for the bridge. The source of tone may be a buzzer a hummer, or an oscillator. As a matter of fact, a radio receiver might easily be used, since there is practically no change in tube characteristics at audio frequencies. The inclusion of a small variometer in the plate circuit to balance out the quadrature of plate voltage due to the grid-plate capacity, is also useful. Care must be taken with regard to the way it is connected into the circuit so that it will not be necessary to take into account its reactance in the final calculation of tube factors. When connected correctly the reactance, which is never greater than 10 or 15 ohms, is in series with the plate impedance. In the other connection this reactance is in series with the balancing resistance and will give absurd results.

MILLER BRIDGE

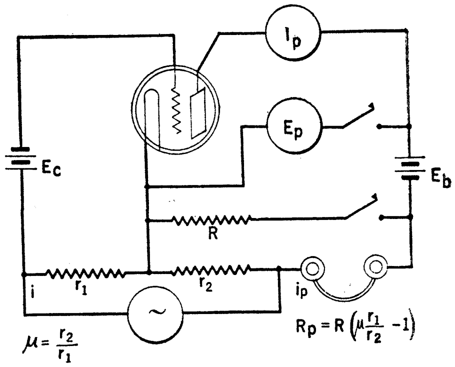


FIG. 6

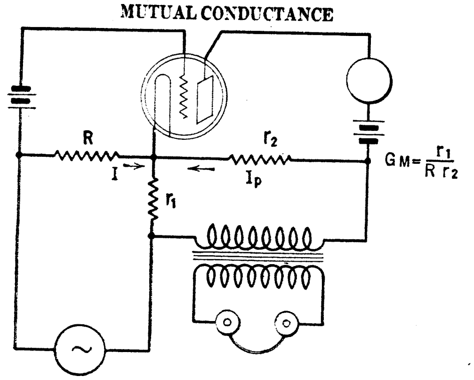


FIG. 8

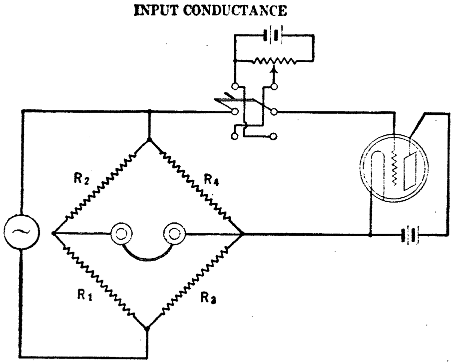


FIG. 9

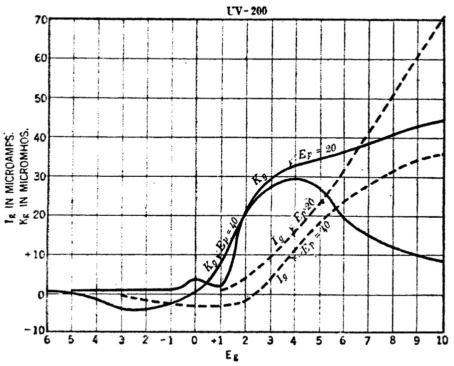


FIG. 10

There are two sources of error in the bridges shown so far. One is in the drop in plate voltage due to the plate current flowing through the balancing resistance. The other is the resistance drop of the indicating device, whether this be a pair of receivers or the primary of a transformer. Trouble from this source may be avoided by making certain that the actual plate-filament voltage is of the value desired after the balance is obtained, and by the use of a low-resistance transformer, such as a modulation transformer, to connect the bridge with the associated audio amplifier. On the Laboratory bridge, a push button connects the plate voltmeter when its reading is desired. Otherwise it is out of the circuit.

In practice, the normal filament, grid, and plate potentials are applied to the tube, and a 1000-cycle current of about one to two milliamperes flows through the bridge arms. To obtain a balance in measuring mu, the resistance in the grid circuit is set at 10 ohms and the plate resistance and variometer varied for balance. Thus, a tube whose mu is 8 requires 80 ohms in the plate side. In a quiet room, and with leads from the oscillator well separated from the amplifier mu can be read to the second decimal place. When tubes of high amplification factor, say 20 to 30, are measured, it is well to reduce the input grid resistance so that a smaller resistance is placed in the plate circuit.

To measure plate impedance with the Miller bridge, the switch is closed and a new balance obtained, when the factor desired is obtained as a function of mu. In both this bridge and in the Laboratory bridge, the resistance, R, against which the tube impedance is compared, may be fixed exactly at 10,000 ohms, although the value is not important as long as it is definitely known. On the Laboratory bridge the plate resistance is set at 100 ohms and the grid resistance varied for balance. If the impedance is 12,000 ohms, R_g will be 120.

MUTUAL CONDUCTANCE BRIDGE

THERE are a number of other bridge schemes for measuring the various factors in which engineers are interested. Ballantine has described several in the *Proceedings of the I. R. E.* One of these is a method of measuring the mutual conductance directly, and for comparing a great many tubes of the same sort under the same conditions, it provides a useful instrument for the laboratory or tube manufacturer, or even dealer. This is shown in Fig. 8. It will be seen that it differs but little from the other arrangements.

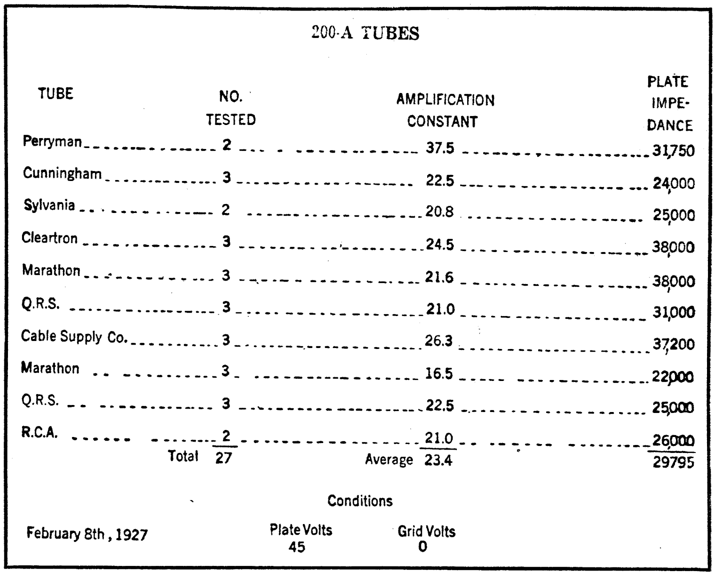
Another set-up of apparatus will measure the input characteristics of the tube at low frequencies. It is shown in Fig. 9. At balance, the grid conductance (the inverse of the input impedance) is given by:

$$K_g = \frac{R_1}{R_2 R_3}$$

and in practice, with normal tubes, all balancing is done with R_1, since R_2 is held constant at 100 ohms, and R_3 at 10,000 ohms. With soft tubes the conductance may change sign at high plate potentials, and it is then necessary to give the input a positive conductance by actually connecting across the grid and filament a high resistance, say of 50,000 ohms. The tube conductance may be obtained by subtracting from this known value, that determined by the bridge. Data given in Fig. 10 on a soft tube show the effect of ionization in giving the input circuit a negative conductance.

TABLE NO. I

Type	Ep	Eg	A.C. Rp	D.C. Res.	Factor	Where d.c. = a.c.
201–A	90	—4.5	11000	30000	2.7	Ep 90, Eg—2
199	90	—4.5	18500	37500	2.0	Ep 90, Eg—3
112	135	—9.0	5500	21400	3.9	Ep 135, Eg—0.6



200-A TUBES

TUBE	NO. TESTED	AMPLIFICATION CONSTANT	PLATE IMPE-DANCE
Perryman	2	37.5	31,750
Cunningham	3	22.5	24,000
Sylvania	2	20.8	25,000
Cleartron	3	24.5	38,000
Marathon	3	21.6	38,000
Q.R.S.	3	21.0	31,000
Cable Supply Co.	3	26.3	37,200
Marathon	3	16.5	22,000
Q.R.S.	3	22.5	25,000
R.C.A.	2	21.0	26,000
Total	27	Average 23.4	29795

Conditions

February 8th, 1927

Plate Volts 45

Grid Volts 0

FIG. 11

COMMERCIAL TUBE TESTERS

THERE are a number of tube testers on the market some of which are very expensive. As far as the writer knows, there is but one which measures tubes according to the bridge schemes outlined above. This is made by the General Radio Company and uses the Miller connections. Others are made by the Hickok Company of Cleveland, by Jewell, Hoyt, and others. The Hickok uses a 60-cycle voltage obtained from a step-down transformer. The others vary the grid and plate voltages by fixed—and it is to be hoped, small—amounts, and obtain the various factors either directly or by simple calculations. They are quite reliable and valuable instruments although not capable of the precision that a true bridge circuit can attain.

It is also possible to obtain tube constants from a knowledge of the d.c. resistance. For a given type of tube, the plate impedance at certain conditions of plate and grid voltage may be obtained by multiplying the d.c. resistance under those conditions by a constant factor; at some other value of plate and grid voltage it will be exactly equal to the d.c. resistance. For example, dividing the d.c. resistance of a 201–A type tube at 90 volts on the plate and a negative 4.5 bias on the grid by 2.7 will give an approximate idea of the a.c. impedance.

Table No. 1 is representative of what may be expected from such methods of estimating tube impedance.

A tube tester with a d.c. plate current meter calibrated with several scales will read the plate impedance with an accuracy that may be all that is desired by dealers and others who do not need to use the values in circuit calculations.

The factors of tubes commonly used to-day are shown in the accompanying tables, Figs. 11, 12, 13, and 14. It is a fact to be thankful for that tubes are now so uniform, since a tube with odd constants placed into a well-engineered receiver is often enough to change conditions from good to very bad. A year ago such standardization had not been reached, as data on file in the Laboratory show.

Now, having shown how various tube factors may be calculated from curves, or measured with bridges or d.c. instruments, it remains to be shown how useful such factors are, and in some measure to justify the statement that mutual conductance is not the determining factor in a tube's goodness or unfitness for particular tasks.

In receivers, as we have them to-day, the first tube generally acts as a radio-frequency amplifier with inductance in both plate and grid circuits. It is necessary that the plate-grid capacity be small and that a given make and type of tube will be uniform. It is also necessary that the input impedance be high and the output impedance be low, for maximum gain. For example, the maximum possible gain from an amplifier is given by the well known expression:

$$K = \frac{\mu}{\sqrt{R_p}} \times \frac{\sqrt{R_g}}{2}$$

and a little mathematics will show that when the proper load is inserted into the plate circuit of a high-frequency amplifier that the maximum amplification will be given by the formula:

$$K_m = \frac{\frac{1}{2}\mu}{\sqrt{R_p}} \frac{L\omega}{\sqrt{R}}$$

where L is the inductance of the secondary coil and R the effective resistance of the circuit. Tube constants enter into other circuit calculations as shown below:

$$\text{Voltage Amplification} = \tfrac{1}{2}\sqrt{R_i} \times \frac{\mu}{\sqrt{R_p}}$$

$$\text{Power Amplification} = \frac{R_i}{2} \times \frac{\mu^2}{R_p}$$

$$\text{Power Output} = \frac{E_g^2}{8} \times \frac{\mu^2}{R_p}$$

where R_i is the input resistance and E_g is the input volts, peak.

112 TUBES

TUBE	NO. TESTED	AMPLIFICATION CONSTANT	PLATE IMPEDANCE	MUTUAL CONDUCTANCE
Cunningham	3	8.3	4660	1785
Daven Mu 6	1	5.3	5150	1060
Diatron	1	6.5	4670	1400
Hercultron	1	9.0	8700	1035
Q.R.S.	1	6.5	5700	1140
Regal	1	9.0	7400	1215
Zetka	4	8.1	7550	1114
Total	12	Average 7.5	6260	1250

Conditions

Plate Volts	Grid Volts
135	-9

February 8th, 1927

FIG. 12

171 TUBES

TUBE	NO. TESTED	AMPLIFICATION CONSTANT	PLATE IMPEDANCE	MUTUAL CONDUCTANCE
Cunningham	2	2.9	2100	1380
Cleartron	3	2.6	2610	1000
Perryman	2	3.15	2650	1190
DeForest	2	2.5	2500	1000
Ureco Special	1	2.5	2000	1250
R.C.A.	5	2.85	2200	1300
Hercultron	1	3.25	2800	1160
Sylvania	2	2.7	2100	1290
Marathon	7	3.1	2600	1190
Total	25	Average 2.84	2395	1195

February 8th, 1927

Conditions

Filament Volts	Plate Volts	Grid Volts
5	135	27

FIG. 13

In every case it will be seen that the tube enters in some ratio of its amplification constant squared, divided by its plate impedance. Knowing this factor, it is only necessary to insert it into circuit equations and calculate the result at once.

There has been much talk among tube manufacturers regarding standardization, and a universal desire is evidenced for a single term by which tubes could be rated. Unfortunately. no such term has been provided simply because no mathematics has been invented that will make such a thing possible. The important factors are the plate impedance, the amplification factor, and the figures for grid and plate voltage under which the values were measured. These data should be on the carton of every tube sold.

Table No. 2 is illustrative of the fact that the mutual conductance of a tube may be lower than another and still have a higher "gain" factor; *e.g.*, compare No. 3 and No. 6 of this table.

CeCo Type K

No.	μ	R_p	G_m	μ^2/R_p
1	11.1	11,700	950	10.5
2	12.1	13,000	930	11.3
3	12.5	15,700	795	10.0
4	11.0	12,200	900	9.9
5	13.1	14,900	880	11.5
6	11.2	13,100	855	9.6
	$E_p=90$		$E_g=-3$	

TABLE NO. 2

201-A TUBES

TUBE	NO. TESTED	AMPLIFICATION CONSTANT	PLATE IMPEDANCE	MUTUAL CONDUCTANCE
Apco	5	6.3	8850	755
Armor	5	7.25	8360	850
Boehm	9	6.95	9030	780
Cable Supply Co.	8	7.4	9810	754
Ceco	6	8.15	11150	736
Champion	5	8.54	13320	643
Cleartron	17	7.1	10420	680
Cunningham	8	8.30	10825	750
DeForest D L 5	4	9.65	11100	885
DeForest D L 2	4	7.15	8625	830
DeForest D L 4	1	8.3	11200	740
Empiretron	3	7.1	10230	694
Fultone	6	8.85	11800	750
Gormac	5	7.15	12400	578
Hytron	3	9.43	14833	635
Ken-Rad	20	8.55	12450	695
Magnatron	2	8.0	12250	652
Marathon	9	8.2	11540	713
Perryman	14	7.6	10350	740
Q.R.S	24	8 2	11440	715
Schickerling RS 10	3	7.93	10167	790
Sky Sweeper	8	7.84	13100	600
Sonatron	4	8.43	13350	632
Strongson	6	8.2	9300	885
Supertron	3	9.5	14600	680
Sylvania	11	8.36	11100	757
Televocal	5	7.1	8000	860
Ureco	15	7.2	9820	800
Van Horne	12	8.63	12800	677
Voltron	19	5.64	7000	845
Zetka	8	8.1	13100	620
Total	225	Average 7.9	10000	735

Conditions

February 8th, 1927

Plate Volts	Grid Volts
90	-4.5

FIG. 14

DETECTOR IMPEDANCE

THERE has been much speculation about the output impedance of a detector tube. This is important in order that amplifier engineers know exactly under what conditions their products will work. For example, it is well known that a transformer-coupled amplifier will have one characteristic working with a tube of 10 000 ohms and another out of 30,000 ohms. Just what is the average impedance of a detector?

It is somewhat difficult to picture what happens when we measure this impedance in one of our bridges. The detector is a distorting device and a pure thousand-cycle note used for balancing the bridge will no longer be a pure note in the output. Furthermore, a detector tube has both high- and low-frequency voltages in both input and output. What effect has this combination of frequencies upon its impedance, if any? Is the impedance of a C-battery detector the same as that of a grid leak and condenser with grid slightly positive? It seems reasonable that the C battery demodulator will have a much higher impedance which may cause us to sit and think when such a device is recommended because of the superior quality of reproduction possible by its use.

There are other problems. For example, shall we place the voltage directly on the grid; shall the plate circuit have a load other than the resistance; shall there be radio-frequency voltages in the circuit?

Several schemes have been suggested to determine whether bridge measurements on distorting tubes mean anything. The one described here is due to Mr. Howard Rhodes of the staff of RADIO BROADCAST Laboratory. It follows from the succeeding consideration. In Fig. 15 is the symbolic representation of a simple circuit in which R_p is the usual tube impedance, and R_o is some other resistance inserted into the circuit and whose value is variable and known. It is simple enough to measure the voltage across this resistance.

Let us suppose the tube impedance, R_p, is 5000 ohms and that we measure and plot the voltage across R_o as the latter is varied. When the two resistances are equal, E_o will be $\frac{1}{2}\mu E_g$ and when R_o is $3R_p$, E_o will be $\frac{3}{4}\mu E_g$, or 1.5 times as much as when R_o and R_p are equal. We shall then get a curve similar to that of Fig. 15. From these data a triangle may be formed whose base is fixed at three units and whose vertical leg is, when $R_p = R_o$, equal to 1.5. It is then only necessary to plot the voltages developed across known resistances in the plate circuit of the detector tube and to form the above triangle on this curve. Some data on detector impedance measured by several methods will be available later. Table No. 3 is the result of bridge methods.

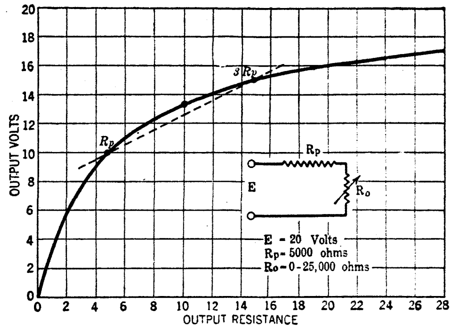


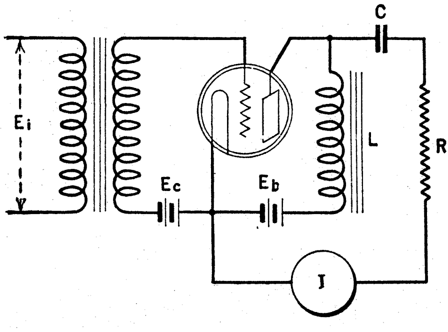
FIG. 15

Tube	Eg	Ep	Rp	R, megs.	C
201-A	—4.5	45	30,000		
201-A	G.L.	45	9500	1.5	0.00025
112	—4.5	45	14,000		
112	G.L.	45	6300	1.5	0.00025

TABLE NO. 3

POWER OUTPUT

THE final measurement in which we shall be interested at present is that of undistorted power output. With the advent of tubes of the 112, the 171, and the 210 class, honest-to-goodness amplifiers have been possible, and many strange misconceptions have arisen from a none too clear understanding of their nature. Some people think that a great increase in volume will result from the substitution of a 171 for a 201-A. Of course such a result is impossible. As a matter of fact the 201-A, with its larger mu, will produce twice as much voltage amplification as a 171, provided the proper impedances are used, but it is certain that more power, with less distortion, will be delivered to the loud speaker when a true power tube is used.



$W_o = I^2 R_o$

FIG. 16

In the first place it may be said that measurement of undistorted power output from present-day tubes seems impossible, for the simple fact that there is no such thing. The question is one of allowable distortion, which involves not only matters of opinion but the particular amplifier and loud speaker used.

It is simple enough to measure the power from a tube. It is only necessary to measure the current through a known resistance, and if the tube constants are known to within ten per cent., and if the grid does not take over 10 microamperes in 350,000 ohms, approximately, the measured power will check the mathematical value to within 10 per cent.

The power developed in the load resistance in Fig. 16 is:

$$\frac{\mu^2 E_g^2 R_o}{(R_o + R_p)^2}$$

And when $R_o = R_p$ this simplifies to:

$$\frac{\mu^2 E_g^2}{8 R_p}$$

where E_g is a peak voltage. If $R_o = 2R_p$ this value becomes:

$$\frac{2\mu^2 E_g^2}{9 R_p}$$

It is well known that the maximum power will be delivered to the loud speaker when the latter's impedance equals that of the tube, and recent data published in this country and in England indicate that the greatest amount of undistorted power will be delivered when the loud speaker impedance is twice that of the output tube. Fig. 17 shows how the power and the voltage gain of a tube vary with input voltage. When the lower bend of the characteristic curve is traversed, considerable rectification takes place, with corresponding change in d.c. plate current. When the plate current has changed roughly 10 per cent. the voltage amplification falls off, and the power output-voltage input curve flattens out.

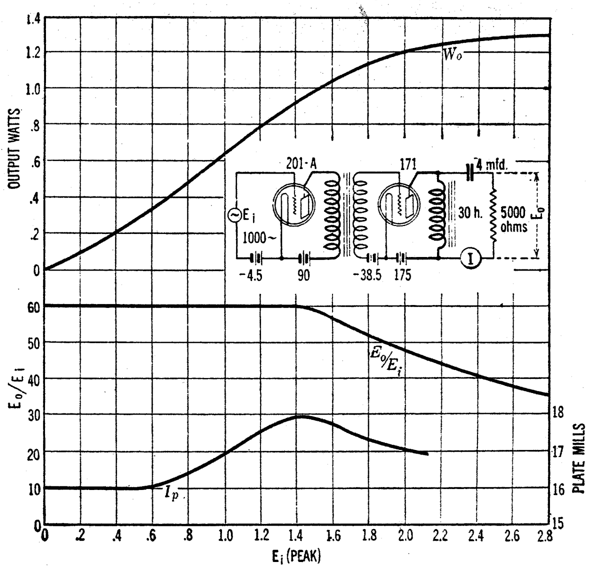


FIG. 18

Fig. 18 differs from Fig. 17 in several respects. Here the grid circuit is fed through a transformer. When the grid goes positive, the characteristic curve flattens out, duplicating roughly the curve at the lower bend. This results in smaller change in average d.c. plate current but a greater loss in amplification. In either case the change in plate current is a fair means of indicating distortion due to positive grid or to rectification at the lower bend.

NEW TUBES

TWO new tubes have been announced recently. One is a 300-milliampere rectifier which will make it possible to run 201-A type tubes in series from rectified a.c., while the other follows a suggestion of Mr. B. F. Meissner, whose paper, delivered before the Radio Club of America paper, on lighting filaments from a.c., was printed in the February and March issues of RADIO BROADCAST. This new tube requires two amperes at 0.6 volts. Naturally the voltage drop across such tubes to r.f. currents is remarkably low. Its thermal inertia is increased vastly over that of even 112 type tubes. The problem seems to be one of making a filament that will have a life comparable to that of other tubes now procurable.

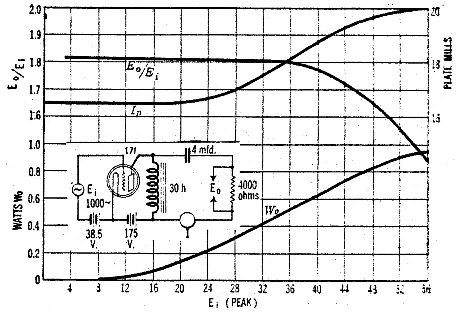


FIG. 17

It must be admitted that there are a great many tube measurements that have not been discussed in this brief paper. For example, there is much to be done with detectors; with the possibility of using amplifiers in which the grid takes considerable current; on the effect of the amplitude of input a.c. voltages upon tube factors; and a host of other interesting and important measurements. There is, at the present time, too much taking the tube for granted, not only by the hundreds of thousands of users, but by manufacturers and engineers as well. A tube is not merely a thing to shove into a radio receiver socket; it is a sensitive and delicate device with a patient and willing nature.

Constant Coupling

The Theory and Application of the Constant-Coupled Non-Reactive Plate Circuit Radio-Frequency Amplifier—A Radio Club of America Paper

By EDWARD H. LOFTIN and S. YOUNG WHITE

When DeForest discovered and announced the three-electrode vacuum tube with the grid interposed between the filament and plate (DeForest patent 879,532, of 1908), he indicated that he looked upon it as a sensitive detector only. We owe the Austrian investigators Lieben, Reisz, and Strauss, so far as our delving into early history has shown (French patent 13,726 of 1911), credit for the beginning of our knowledge of the amplifying and repeating ability of this tube, and more particularly for our knowledge of the universal character of these abilities.

Prior to the French patent of these Austrian investigators, there seems to have been no particular grasp. by those few individuals who had contact with the three-electrode tube, of what happend to alternating currents introduced into the grid circuit after they encountered the tube, other than the general impression that the spark or damped form of currents, then in vogue for radio signaling, lost, in some unexplained way, their high-frequency character, and appeared in the plate circuit as low-frequency components having the group frequency of the original spark waves.

Lieben, Reisz, and Strauss not only taught that alternating current of any and all frequencies could be repeated and amplified in like form, but made the suggestion, at once obvious from the knowledge that the alternating current appeared in like frequency and form in the plate circuit, that it could be passed on to additional three-electrode tubes to continue the amplification to any desired degree without loss of frequency or form. In other words, this was the starting point of our cascaded vacuum-tube repeating with amplification, though the cascading was certainly no great engineering step in view of the then already old practice of cascading microphone amplifiers. The utility was merely extended by the important step of ascertaining that the vacuum tube is not limited by inertia effects that shackled the microphone to a low order of frequencies.

From the 1911 date of these Austrians, the three-electrode tube leaped forward as an amplifier, being eagerly taken up wherever amplifying repeaters had a function to perform. Where one tube did not give the amplification desired, cascading was resorted to, as prompted by the early microphone practice and its reiteration in the French patent. Low-frequency work, such as telephone systems, went forward without any great difficulty, but there was still hidden away in the new amplifier an effect that was to have great bearing on and hindrance to its application to the higher frequency work of radio practice. This effect is one which depends upon the nature of the reaction of the plate circuit on the amplified current and the accompanying feed-back of energy through the grid-plate or inherent capacity of the tube, which effect becomes increasingly manifest as the frequency dealt with increases towards that region where the small inherent tube capacity becomes an effective path or coupling for the transfer of energy. Most of us appreciate what an effective path it constitutes in the broadcast band of frequencies.

We have recently commented on this effect in papers that have been rather widely published, so that it seems unnecessary to repeat our comments here beyond the now well recognized knowledge that the amplification performance of a three-electrode vacuum tube, when operating at the higher frequencies, can be varied through an enormous range by varying the nature of the reaction of the plate circuit from highly capacitive, through nonreactive, to inductive, the amplification going from low to high as the reaction is varied in the order mentioned, until finally the feed-back is sufficient to cause the system to become a generator of oscillations.

Lieben, Reisz, and Strauss, in proposing cascading, showed (Fig. 5 of the French patent, reproduced here as Fig. 13 in simplified form) two identical stages of amplification. Knowing with certainty from the teaching of these investigators that the current in the plate circuit of the first tube is the same in frequency as the current in the grid circuit, the skilled man of that time intuitively and of necessity tuned the second stage the same as the first to get efficient transfer of energy. The telephone man used in each stage without question the transformers he had long since designed as tuned to his order of low frequencies, and with equally empirical procedure the radio man tuned, with air-core coils and condensers, for his order of frequencies. The telephone man was immediately successful, but the radio man (Schloemilch & Von Bronk patent 1,087,892; Reisz Patent 1,234,489; Armstrong Patent 1,113,149; Alexanderson Patent 1,173,079.) encountered the not understood inherent tube capacity which converted his attempts at tuning either directly in, or in association with the plate circuit, into variable plate circuit reaction production that made his early days of attempted cascade tuning nightmares of squealing. It was not until Rice (Rice patent 1,334,118.) provided a means for neutralizing the troublesome tube capacity that the radio man took his first step towards actual cascaded tuned radio-frequency amplification.

While the step of Rice was one of pronounced merit from the scientific point of view, yet it was fraught with grave difficulties from the multiple practical application or manufacturing point of view. Being, as it is, a bridge or balance method in which the troublesome tube capacity constitutes one leg of the bridge and in which the radio set manufacturer must furnish the balancing leg, it is obvious that what the manufacturer furnishes is of doubtful value where tubes must be made by the million to meet the present-day demand, with consequent variations in tube structures that go hand-in-hand with quantity production and diverse sources of supply.

Then, too, we all know from high-frequency bridge work that a balance is good for only one frequency, so that when we come to applying a bridge method to all the frequencies of the very wide band of broadcasting without some follow-up corrective adjustment, the overall result becomes extremely doubtful, making the necessity for constancy of tubes in manufacture all the more pressing. While a tube may be slightly different in capacity from that with which the radio set manufacturer neutralized a bridge type of set, and may not cause trouble at the one frequency at which neutralizing is possible, oscillations are most prone to occur with this off-capacity tube at other frequencies in the broadcast band.

It has been suggested that the defect of Rice as to the single frequency neutralization characteristic might be corrected by using 100 per cent. coupling in the reverse feed coupling of his bridge but such a suggestion does not satisfy the practical man because of its impracticability in general and unsuitability in high-frequency selective systems where tight coupling destroys the selectivity that is necessary to put a radio receiver in the commercial race of to-day. Of course, this 100 per cent. coupling suggestion offers nothing towards the solution of the problem of quantity production variability of tube capacities.

Another natural step of the radio man in cascading tubes was the use of the old inductive or transformer coupling, and it was not until broadcast receivers commenced to cover a wide range of frequencies in commercial competition that it was appreciated that this form of coupling was providing such a wide difference in efficiency at the short wavelengths over the long wavelengths, this of course being due to the energy transfer from stage to stage falling off with decrease of frequency through the inductive coupling. This same fact caused the reaction of a tunable circuit in a succeeding stage on the plate circuit of a preceding stage to be much stronger on the shorter wavelengths than on the longer, and as tuning such a circuit is bound to bring it to that point where an inductive reaction predominates, there resulted a much greater tendency to oscillate on the shorter wavelengths. Any corrective measures to overcome this tendency merely further lessened the efficiency on the longer wavelengths.

We have developed a circuit which we term "constant coupled-non-reactive plate" which accomplishes the dual function of overcoming the inequality of energy transfer throughout the broadcast band and of preventing the plate circuit from being caused, by the tuning of a succeeding coupled circuit, to react in that inductive way that has heretofore caused the tube capacity to be troublesome, and which does this not only for one frequency but for all frequencies.

Obviously, if we remove the troublesome reaction, then we are totally unconcerned with what the tube capacity may be. Once stabilized for any tube, no difficulty arises by using any and all other tubes as may suit the fancy of the set purchaser.

EXPERIENCES WITH THE CIRCUIT

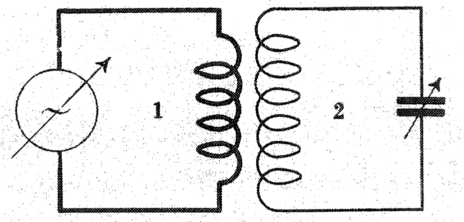


FIG. 1

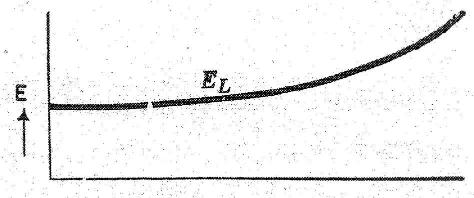


FIG. 2

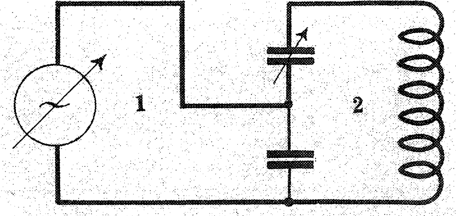


FIG. 3

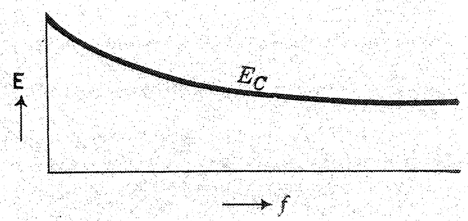


FIG. 4

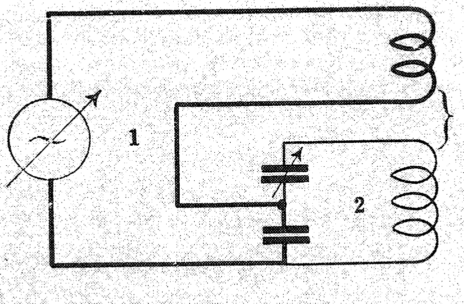


FIG. 5

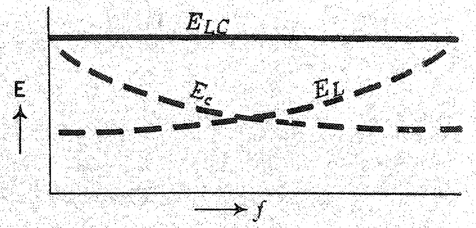


FIG. 6

WE WILL comment but briefly on the theory of our circuit and then proceed to the prime purpose of this paper, namely outlining, with practical constructional data, some of our experiences in order that those who are interested may investigate the operation or construct radio receivers employing the system.

Fig. 2 illustrates graphically the increasing type of energy transfer, with frequency, between the two electromagnetically coupled circuits of Fig. 1. Changing to the electrostatic form of coupling, as shown in Fig. 3, the type of energy transfer takes the reverse or falling form with frequency as shown graphically in Fig. 4. By selecting the relative values of the coupling condenser and the variable tuning condenser we can cause the slope of the energy transfer, curve E_C, to be anything desired. For example, with a tuning condenser having a range of from 500 maximum to 20 minimum, employed with a coupling condenser of 2500, the coupling will taper from roughly 20 per cent. on the long-wave end to 1 per cent. on the short-wave end. With a coupling condenser of 5000, the coupling will taper from roughly 10 per cent. to one-half of 1 per cent., thus giving a wide variation of slope of curve E_c for the two conditions. This is one of the principal variables around which we work to get the final result, as will be more specifically pointed out later.

Combining the electromagnetic coupling and electrostatic coupling, as shown in Fig. 5, and giving the electromagnetic such polarity (merely reversing connections to primary) that it transfers energy in phase with the electrostatic, we get a combined energy transfer that is shown graphically in Fig. 6 by the curve E_{LC}, which curve may be made substantially horizontal, representing uniform energy transfer with frequency, or may be made to slope either up or down by adjusting the electrostatic coupling values as before mentioned.

The reaction of circuit No. 2 on circuit No. 1 of Fig. 5 follows the same law as the rate of energy transfer shown in Fig. 6, so that if we insert the combined electromagnetic and electrostatic coupling between the plate circuit of a tube and the grid circuit of a succeeding tube, as shown in Fig. 7, which includes a choke coil to permit the direct current plate energy to bypass the electrostatic coupling condenser, we can make the tuning of the grid circuit create any desired reaction with frequency on the plate circuit by adjusting the coupling as before outlined. For instance, we can cause the curve E_{LC} in Fig. 6 to slope downward to more tend to create oscillations on the longer wavelengths, which is the reverse effect of ordinary inductive coupling, or, by adjusting to make the curve E_{LC} substantially horizontal, we can keep regeneration uniform throughout the band to keep just below the oscillating point for maximum amplification, or just within the oscillating state throughout.

Thus, the combined coupling permits us to transfer energy between two circuits at any predetermined rate with variation of frequency, as between the antenna and grid circuit of the first tube, or to choose the way we wish the reaction of a tunable circuit coupled to the plate circuit of a tube to react with frequency on the plate circuit as the coupled circuit is tuned. This latter feature is a most effective means of attack on the troublesome inherent tube capacity, for now we can put a capacitively reacting element, as the condenser C in Fig. 8, in the plate circuit, the reactance of which will decrease with frequency, and by adjusting the coupling of the tunable circuit No. 2 so that the tuning of the circuit will produce an inductive reaction equal to and decreasing with the capacitive reaction with frequency, we arrive at an overall plate circuit that is non-reactive throughout the broadcast band. Thus we eliminate the thing that causes the trouble, namely the particular kind of force that is necessary to drive energy back to the grid in phase with the grid energy, so that thereafter it makes no difference what the tube capacity may be.

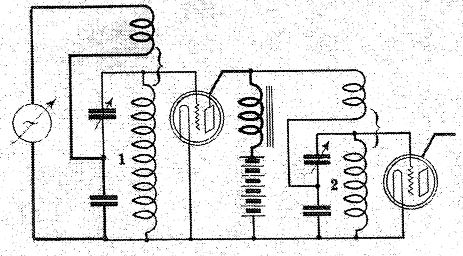


FIG. 7

Of course, if the reactance of the condenser C is not sufficiently large, regenerative amplification will take place, but it may be kept uniform throughout the band. If the reactance is too large so that the plate circuit reaction remains capacitive in nature, degeneration or reduction in amplification will be obtained. This latter effect may be found useful under conditions where the construction of the receiver brings in stray or distance stage feed-back of a regenerative or positive character, for a proper amount of reverse feed-back through the tube elements may then be injected into the system to overcome the positive stray feed-back to give an overall stable system. This is a result that cannot be obtained in the Rice form of bridge balance in which neutralization is the limit with nothing on the side of degeneration.

The practical design of apparatus employing our principles may best be illustrated by the construction of a single stage of radio-frequency amplification which is regenerative throughout the broadcast band, and then stabilizing this stage by the application of the non-reactive plate circuit. The unstable form of the first step shows up quite markedly any defect in design or choice of constant that might be small enough not to be noticed in the stable form. The circuit is shown in Fig. 9, and the constants actually used by us in constructing such a model will be given.

The coil and condenser combination for the tunable circuit must be chosen to cover the broadcast band with due allowance for the fact that the maximum effective capacity of the tuning condenser, C_2, is lowered by having the capacity of the coupling condenser, C_1, in series in the same circuit. The coil is preferably of moderate to small diameter to lessen interstage coupling. Our coil has 70 turns of No. 26 double silk-covered wire closely wound on two-inch tubing. The tuning condenser has the maximum

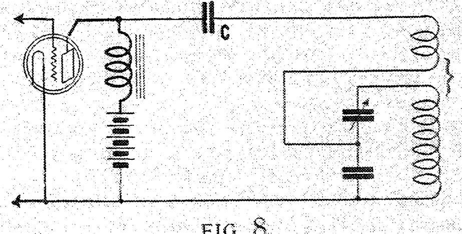


FIG. 8

capacity of approximately 500 micromicrofarads (0.0005 mfd.), and in actual use the combination covers the band of 182 to 600 meters (1647 to 500 kc.).

The first coupling to be considered is the one between the antenna and first tube. The primary L^1 may be of from 4 to 12 turns, depending upon looseness of coupling desired on the shorter wavelengths. In the model we are describing we have 10 turns. The primary should be closely coupled physically to the low-potential or ground side of the secondary coil L^1, as by winding on tubing of slightly smaller diameter so that the primary will fit snugly inside the low potential and off the secondary.

The coupling, condenser C^1_1 should be so chosen in capacity as to give the desired increase in coupling on the longer waves, and may run from 3000 to 6000 micro-microfarads, depending upon whether tight or loose coupling is desired for the longer waves. The smaller the capacity the tighter the coupling. A capacity value of 4000 mmfd. is used in the model principally because this value is used for the interstage coupling condenser C_1, and permits the two dial readings of the model to be the same as the settings for maximum tuning capacity. The matter of the coupling between the antenna and first tube is not so critical as the coupling between tubes.

Proceeding to the output circuit of the tube, it will be noted that the plate is energized through a choke because the coupling condenser, C_1, interrupts the plate circuit for direct-current flow. This choke may have a fairly wide range of constants, the one in the model comprising 350 turns of No. 36 enameled wire wound on a small, flat bobbin, the distributed capacity being 4 micro-microfarads.

Considering the electromagnetic coupling, the coil L_1 should have as large a mutual inductance with coil L_2 as is convenient, while retaining a small self-inductance. That is, the coil should be physically close to L_2 but should have a small number of turns. In the model, L_1 has 9 turns closely and adjustably coupled to the low potential end of L_2.

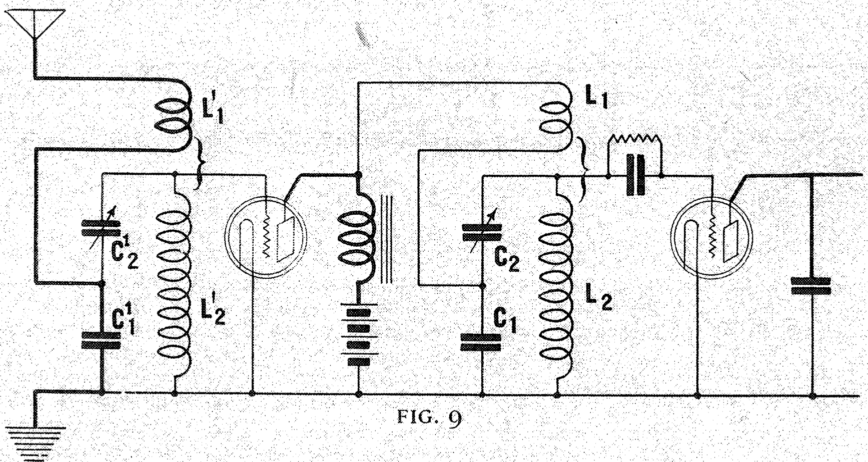


FIG. 9

In the electrostatic coupling the coupling condenser, C_1, is made adjustable by having a small variable capacity condenser of the screw-down or mica compression type in parallel with a fixed condenser of the mica type. The fixed condenser has an actual value close to 4000 micro-microfarads, and the adjustable condenser has a minimum of 250 and a maximum of 850. The combination is usually so adjusted to give a total capacity to C_1 of about 4500 mmfd.

With the elements so chosen and arranged, the receiver can now be set up, but extreme care must be taken to see that the electromagnetic coupling is so poled as to transfer energy in phase with the electrostatic coupling, otherwise the two will neutralize somewhere towards the middle of the band and there will be zero coupling with no energy transfer. If this situation is found, reverse the connections to the coil L_1. After setting up, tighten the couplings until oscillation occurs freely over the entire broadcast band. Then stop oscillations by lowering the filament temperature of the tube, and note whether the oscillations stop more readily on the shorter waves than on the longer, or vice versa. If the former condition is manifest, either decrease the electrostatic coupling (increase capacity of condenser C_1) or increase the electromagnetic coupling. If the latter condition is present reverse the corrective process, leaving the coupling so adjusted that the regenerative tendency is about the same at both ends.

When this adjustment is completed, it may be found that the tendency towards regeneration is not as strong towards the middle of the band as at the ends. The circuit of Fig. 10 may be used to overcome this effect, as it introduces loss to any desired amount at either one or both ends of the band consisting, as it does, of connecting a resistor, R, from the branch point of the two condensers to a point on the inductance which is equipotential at the adjustment of tuning condenser C_2 which corresponds to the wavelength where it is desired that no loss be introduced. As we tune to either side of this point, potentials will develop across the resistor producing a resulting damping action to hold down any tendency towards regeneration. This, however, is not our usual method of correcting this apparent valley effect in the regenerative tendency.

The condition is caused in the main by stray feed-back, so that a more logical attack is to keep such feed-back small, or nil, as far as possible. If it is found that this feed-back cannot be satisfactorily eliminated by arrangement of parts, wiring, and angulation of coils, a shield placed between the variable condensers will be helpful, to avoid undue consideration of the stray feed complication, we would suggest, starting with such a shield.

The detector and audio amplification used are conventional. The audio should have a minimum of distortion, for when the set is finally stabilized by the addition of the plate circuit phasing condenser, a signal of such marked clarity is delivered by the radio-frequency and detector portion of the system that it is well worth preserving.

The regenerative single stage so far arrived at has marked sensitivity and apparent selectivity, but, of course, most marked distortion. The next step therefore is to eliminate the distortion, which is done through application of the non-reactive plate principle, involving inserting the proper value of phasing condenser, C_3, in the plate circuit and adjusting the combination coupling for the proper reaction to neutralize the capacitive reaction of the phasing condenser.

This phasing condenser, C_3, has a capacity value in the neighborhood of 1000 micro-microfarads, but should be variable within small limits on either side of this value. In the model, we have a variable compression type as before described, in parallel with a fixed mica condenser of 500 micro-microfarads, giving a range from 750 to 1300 mmfd.

It might be mentioned here that in the regenerative form we are strictly limited in our choice of couplings to those values which will produce the desired regeneration, but that the addition of C_3 allows either tight or loose coupling throughout the band, which tight or loose coupling can be compensated by adjusting C_3 to be small or large respectively.

When C_3 is actually adjusted it will perhaps be found that an uneven effect will be produced in going from one part of the broadcast band to another, but this can be corrected by varying the couplings until the desired smooth effect is obtained. These adjustments are much less critical than in the regenerative form.

Proper adjustments of the couplings will allow C_3 to have even effect throughout the band. It will be found that if C_3 is large in value, with consequent small reactance, regeneration or even oscillation will take place. As its value is lowered, these effects will disappear and true non-reactive plate circuit operation will be obtained. Further decrease of the value of C_3 will cause a reverse feed-back through the tube with increasing loss of sensitivity and selectivity. It will be noted that we do not go from oscillation down to a balance point and then return to oscillation, as is the case in adjusting a bridge method of tube capacity neutralization, but go from oscillation through neutral to degeneration, which cycle allows us to overcome any conditions of feed-back within reason.

When we arrive at the non-reactive adjustment, we find that no change of plate or filament potential or tube capacity will cause regeneration or oscillation, this because the phasing of the plate impedance will not allow a favorable feed-back through the tube elements. In practice, tubes of any type, amplification constant, or capacity can be interchanged, and the only consequence will be increased or decreased output due to the varying amplifying properties of tubes. The quality of the signal is unmarred by regeneration.

Continuing to the multiple-stage amplifiers, the procedure above outlined provides for considerable familiarity with the constants to be chosen. It is particularly emphasized that the experimenter should familiarize himself with

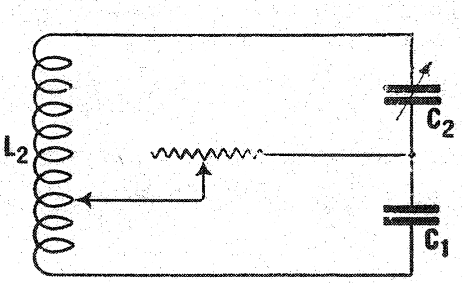


FIG. 10

the single-stage arrangement before attempting multi-stage design.

The multi-stage amplifier is most practicable in the stable or non-reactive plate form. The constants for each of the stages are roughly equivalent to the single stage. Primary coil L_1 may have 7 turns tightly coupled to the secondary, L_2, and coupling condenser C_1 may be about 3500 micro-microfarads. Condensers with shaped plates are quite suitable for the system since the actual selectivity obtained is quite marked at the short waves. In general, the coupling condenser, C_1, should have from 6 to 9 times the capacity of the tuning condenser C_2. Phasing condenser C_3 should be variable in order that the receiver may be finally adjusted for non-reactive plate, which means freedom from distortion and certain freedom from oscillation. The experimenter is cautioned that his particular placement of parts may result in stray feed-back that will make changes of constants from those given above more or less necessary.

The regenerative type of detector, shown in Fig. 11, is somewhat novel. Its purpose is to give constant coupling, or tickling, between the plate and grid circuits so that it can be kept below oscillation for maximum regenerative amplification throughout the broadcast band, thus eliminating the constant follow-up adjustment of a tickler or like arrangement. Or it might be kept constant in the oscillating state for autodyne reception in telegraphy work. The constants are similar to those given above. Assuming C_2 to be 500 micro-microfarads, C_1 will be in the neighborhood of 4000 mmfd. and C_3 about 250 mmfd. L_1 is about 8 turns tightly coupled to L_2. C_3 should be made variable so that the right amount of feed-back can be obtained for a given setting of filament rheostat and plate voltage, and with a constant adjustment of coupling the feed-back will remain the same throughout the band.

It will be noted in Fig. 11 that we connect the grid and filament directly across tuning condenser C_2, which is made necessary in order that the feed-back from the plate circuit will be in phase with the grid circuit energy. This same form of connection is necessary in multi-stage receivers where the rotary elements of the several tuning condensers are connected through a common link for unitary control as in the single-dial receiver. The arrangement for a single stage is shown in Fig. 12, which requires a choke coil, L_3, or high resistance across either coupling condenser C, or tuning condenser C_2 to permit of biasing the grid of the succeeding tube. This arrangement is embodied in the "Single Six" receiver of the Hartman Electrical Manufacturing Company, which uses our system and has single-dial control. It is obvious that this form of connection gives a varying voltage across condenser C_2 as tuning takes place, thus bringing in another variable which must be taken care of in adjusting the coupling, so that we recommend this arrangement only for those systems where single-dial control makes it necessary.

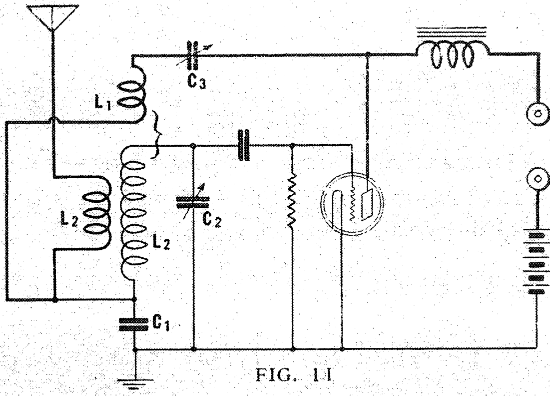


FIG. 11

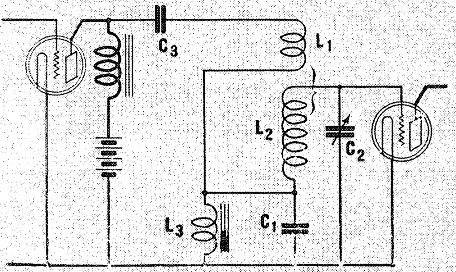


FIG. 12

While we have pointed out many variables and adjustments it is not to be inferred that all of them are necessary for commercial receivers in quantity production. In fact they can all be designed sufficiently close to give the desired results, leaving but one element variable for a simple final adjustment to correct for discrepancies in manufacture, which is precisely what is done in the Hartman "Single Six" receiver referred to.

Properly designed, the above circuits are of marked utility in solving some of the problems in radio receivers which must cover the wide frequency band of broadcasting. Once the operating principles are grasped, employment of them presents no great difficulties to the skilled experimenter.

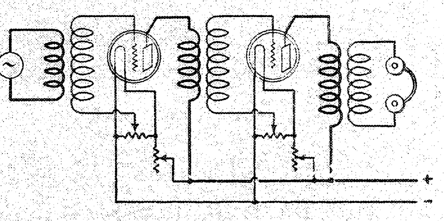


FIG. 13

1927 BANQUET AND ENTERTAINMENT

OF THE

Membership of The Radio Club of America

THURSDAY, MAY 12th, 1927

Hotel McAlpin (Green Room) New York City

Those who were fortunate enough to be present at our 1926 Banquet know how successful an event it was. Plans for our 1927 Banquet are well under way and it promises to be of the same successful order.

The 1927 Banquet Committee: Davis S. Brown, Chairman; Arthur Lynch, Pierre Boucheron, Thomas J. Styles.

Members may invite their friends to this Banquet. Tickets, as usual are $4.00 per person.

Radio Club of America

THAT CLUB HOUSE OF OURS

A serious effort is under way toward the realization of a long cherished idea: A Permanent Club House. In fact the Club House shows some promise of developing into an actuality, rather than a visionary idea. In due course a plan to this end will be submitted to the membership of the Club by the recently appointed Club House Committee.

Club House Committee: CARL DREHER, *Chairman;* ROBERT H. MARRIOTT, GEORGE E. BURGHARD.

HAVE YOUR 1927 DUES BEEN PAID?

The Membership Committee has received from the Club Treasurer a report of dues in arrears. A number of members have slipped into the habit of neglecting the payment of their dues for several years. The Club has been very lenient with such cases in the past, but greater systematization of its affairs requires that they be dealt with strictly in accordance with Article IV of the constitution, to wit:

> "Sec. 2—The Annual Dues shall be payable on the first day of each calendar year in advance of the ensuing year.
>
> "Sec. 5—Any Member or Fellow whose dues become two months in arrears shall be notified by the Treasurer. Should his dues then become four months in arrears, he shall again be notified by the Treasurer. Should his dues then become six months in arrears HE SHALL FORFEIT HIS CONNECTION WITH THE CLUB."

The treasurer will appreciate your coöperation in this matter. Your remittance should be addressed: Joseph Stantley, Treasurer, 15 Warren Street, New York City.

MEMBERSHIP CERTIFICATES

As previously announced, membership certificates are available to those desiring them, no charge being made for the certificate where spaces for name, grade, etc., are filled in with ordinary handwriting. Many members, however, have had their certificates filled in by an artist. The charge for this is One Dollar. The certificate is splendidly engraved and really worth having. Applications for these certificates should be made to the Corresponding Secretary, specifying whether or not it is to be engrossed by the artist, in which case remittance of One Dollar should be included.

CLUB EMBLEMS

The Treasurer has on hand a considerable supply of Club emblems, in the form of a pin with the Club insignia in black and gold. The cost is $3.00 per pin. These are kept on hand for the convenience of the membership and are sold practically at cost.

1927 YEAR BOOK

The initial distribution of the 1927 Year Book will be made at the Club Banquet on Thursday, May 12th, as was done last year.

PAPERS AT OUR MONTHLY MEETINGS

Suggestions as to subjects in which members are interested are welcomed. The next meeting will be held in Room 309, Havemeyer Hall, Columbia University, at which a paper will be read by Mr. Lloyd Espenschied of the American Telephone and Telegraph Company on a subject which will be announced in the regular notices by mail.

L. G. Pacent
Chairman Committee on Papers
91 Seventh Ave., New York, N. Y.

Pierre Boucheron
Chairman Committee on Publications
Room 2040, 233 Broadway, New York, N. Y.