Little-Known Tubes

The UX-841 and 842

By Harold P. Westman, *Technical Editor*

There have been developed a number of special-purpose tubes concerning which the amateur and engineer knows little. This is the first of a series of articles describing some of these tubes which are capable of performing duties for which the better-known tubes are not so well suited. — EDITOR.

THE last few years have certainly been prolific ones as far as the development and marketing of vacuum tubes is concerned. At the present time there are, perhaps, two dozen tubes from which one picks those desirable for use in a receiving set. While for obvious reasons the receiving tube has had the bulk of attention, one must not overlook the advances made along the line of rectifier and power transmitting tubes as well.

Assuredly, it would seem that there could be little reason for the existence of any other tubes than those readily available on the market. However, one may find a number of conditions into which these well-established tubes do not fit and it is to meet some of these that special tubes have been devised.

It would indeed be difficult to find someone who is not familiar with the UX-210. Its uses are manifold and varied and one finds it in the receiver as well as the transmitter. We are also aware of the UX-865, the screen-grid 7.5-watt tube. Few, though, know of the existence of two other tubes in the 7.5-watt family. These are the UX-841 and the UX-842, high-μ and low-μ tubes respectively. They are designed for use in certain circuit arrangements for which the 210 is not so well adapted.

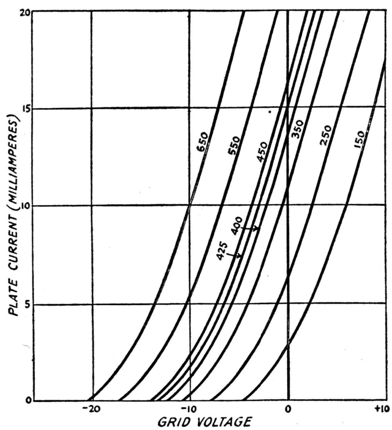

FIG. 1. — PLATE CURRENT VS. GRID VOLTAGE FOR THE 841

The numbers on the various curves indicate the plate voltage at which the curve was taken.

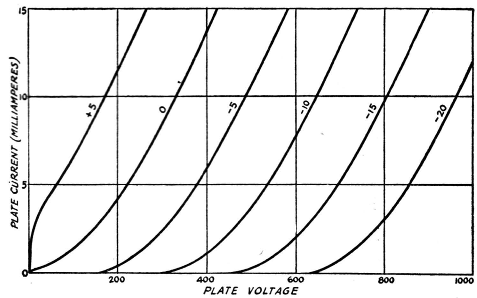

FIG. 2. — THE PLATE VOLTAGE-PLATE CURRENT FAMILY FOR THE 841

The grid voltages under which the curves were made are indicated on the curves.

The filaments of these two tubes are identical with that of the 210. There is little need be said about this element other than that a total emission of about 700 milliamperes is available when the voltage applied across its terminals is 7.5 and that this is reduced to approximately 175 milliamperes when the voltage is dropped to 6.

UX-841

We will first consider the UX-841 which has a high amplification factor or μ and is ideally suited for use in resistance or impedance coupled amplifiers when a tube of this power rating is essential. It may, perhaps, some day be the "for use in last audio stage only" tube in sets feeding electrostatic loud speakers concerning which we have been hearing a bit of late. Such speakers require high signal voltages for their satisfactory operation and it would seem that the 841 would be well-suited for the task. This is particularly true if one insists upon ample volume to indicate to the neighbors the possession of a "powerful" receiver as now seems to be the mode.

While it has no advantage over the use of a 210 as an ordinary oscillator, it does have a distinct advantage as far as its operation as a voltage amplifier is concerned. It is excellently suited for use in the crystal-controlled transmitter and may be employed as the crystal oscillator tube or as an intermediate amplifier between the crystal tube and the power stage. Although in

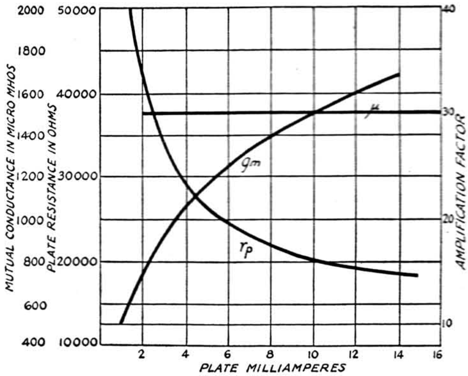

FIG. 3. — CURVES FOR THE PLATE RESISTANCE, MUTUAL CONDUCTANCE AND AMPLIFICATION FACTOR ARE PLOTTED AGAINST PLATE CURRENT ABOVE

These are for the 841.

this latter *rôle* it does not offer the advantages of the 865, both in gain and isolation between input and output circuits, it is much nearer within the reach of the amateur in price, a consideration of no small size.

Some idea of the ratings of the tube may be obtained from the following:

	Resistance coupled amplifier	*Oscillator*
Filament voltage	7.5	7.5
Filament current	1.25 amps (max.)	1.25 amps.
Plate voltage	425 (max.)	350 (max.)
Safe plate power dissipation	12 watts	15 watts (max.)
Output	Undistorted peak output voltage 250 volts	7.5 watts

With a filament voltage of 7.5, a plate voltage of 425 and a negative bias of 8 volts, the following characteristics are obtained:

Amplification factor	30.
Plate resistance	21,500 ohms.
Mutual conductance	1.4 ma./v.

The direct inter-electrode capacities are:

Plate to grid	8. μμfd.
Grid to filament	5. μμfd.
Plate to filament	4. μμfd.

Figs. 1 and 2 show the effect upon the plate current of changes in either the plate voltage or the grid voltage. For a given value of plate and grid voltage, the plate current can be obtained from Figs. 1 and 2 and by applying this value to Fig. 3 one can ascertain the plate resistance, mutual conductance and amplification factor. This latter characteristic is constant at 30 over the range shown. The curves for plate resistance and mutual conductance are not applicable when the tube is oscillating because they are based upon very small input voltages and if the input is of more than a few volts these values do not hold.

Fig. 4 shows plate current vs. plate voltage curves. In addition, load lines for various values of plate load resistance are drawn in. These lines indicate the drop across the load resistor due to the plate current flowing through it and assume a supply voltage of 425. The voltage applied to the plate of the tube is that at which the plate current-plate voltage curve and the load line cross. Three values of grid bias are considered.

When the tube is used as a resistance-coupled amplifier, the maximum signal voltage that it can handle will depend upon the amount of distortion permitted. Under normal conditions the amount of distortion allowable is that which causes the generation of a second-harmonic of about 5 per cent. In practise in order to obtain as much output as possible, this value is usually held between 4.75 and 5.25 per cent. and it may be calculated by the following equation:

Per cent second harmonic =

$$\frac{\frac{1}{2}(I_{max}+I_{min})-I_o}{I_{max}-I_{min}} \qquad (1)$$

where

I_{max} = Plate current at least negative grid voltage.

I_{min} = Plate current at most negative grid voltage.

I_o = Steady plate current (no signal input).

As an aid in the design of resistance-coupled amplifiers, the curves of Figs. 5 and 6 are shown.

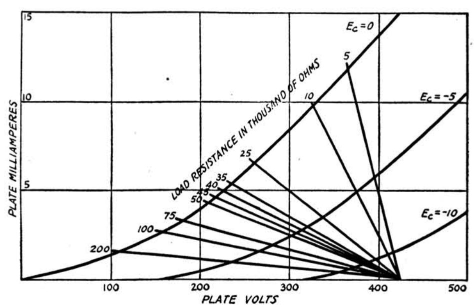

FIG. 4. — IN THE ABOVE, THE LOAD LINES HAVE BEEN DRAWN IN OVER THE PLATE VOLTAGE-PLATE CURRENT CURVES SO THAT DISTORTION MAY BE CALCULATED

The grid bias values are indicated on the curves.

Fig. 5 considers the case of an amplifier operated from a supply voltage of 425 and shows the value of bias necessary for any value of plate load resistance between 10,000 and 100,000 ohms. The maximum grid swing permissible will be equal to the bias as the grid should draw current under no conditions. The voltage amplification and output voltage for maximum grid input voltage are obtainable directly from the curves. The limiting factor for small values of load resistance is the curvature of the plate-voltage plate-current curves. When larger values of load resistance are employed, the plate current may go to zero which is the minimum current limit.

The use of a 425-volt supply does not allow the full gain to be had because the plate voltage will always be less than the rated value. When additional voltage is not available this cannot be avoided. However, the output of the tube may be fed to the grid of a 50-watter and if we employ the 1,000-volt plate supply for this tube on

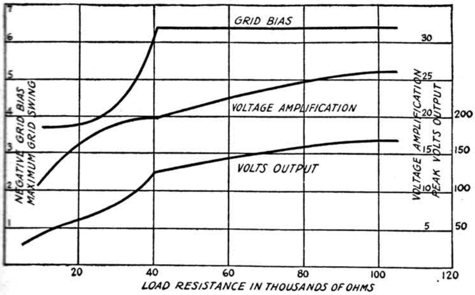

FIG. 5.—THESE CURVES WERE CALCULATED TO SIMPLIFY THE PROBLEM OF DETERMINING THE PROPER BIAS FOR THE 841 WHEN THE SUPPLY VOLTAGE IS 425 AND THE LOAD RESISTANCE IS KNOWN

The voltage amplification and maximum undistorted peak output voltage may also be directly obtained.

the 841, a material improvement in its operation will be obtained. It allows the use of much higher load resistors and Fig. 6 shows the bias necessary, output voltage and amplification possible for values of plate load resistance between 0.1 and 1. megohm.

In this case it is essential that the input signal be limited to a value that does not drive the mean plate voltage above 425 volts. It is this rather than distortion due to the generation of harmonics that limits the permissible output.

When the higher values of plate load resistance are used, it is possible for the grid leak through which bias for the succeeding tube is obtained to affect the operation of the tube by reducing the load resistance. The blocking condenser usually employed has a low impedance compared with the resistors involved and the grid leak can be considered as being in parallel with the load resistor. While this does not affect the operating point as far as the d.c. voltage applied to the plate is concerned, it does affect the generated a.c. voltage which is applied across the two resistors in parallel. So much for the 841!

UX-842

The UX-842 is a low-impedance type tube and is designed for operation as a speech-operated power amplifier and modulator. It has no advantage over the 210 when employed as an oscillator, while its low plate impedance may be considered as a disadvantage in that more careful

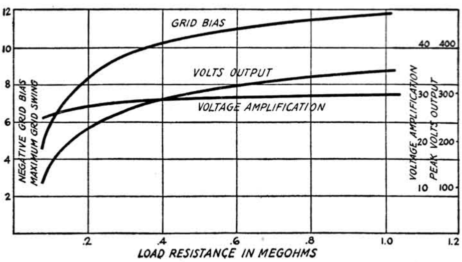

FIG. 6.—WHEN THE SUPPLY VOLTAGE IS 1000 VOLTS, A MUCH LARGER LOAD RESISTOR MAY BE USED AND THE AMPLIFICATION AND MAXIMUM OUTPUT VOLTAGE WILL BE MARTIALLY INCREASED

These curves show the proper bias and voltage output and amplification when this higher supply voltage is available.

circuit design and adjustment are necessary. It is accordingly, not recommended for oscillator use. Its rating is given below:

	Speech amplifier or modulator	
Filament volts	7.5	
Filament amperes	1.25	(max.)
Plate voltage	425.	"
Safe plate power dissipation	12. watts	
Output	3. "	

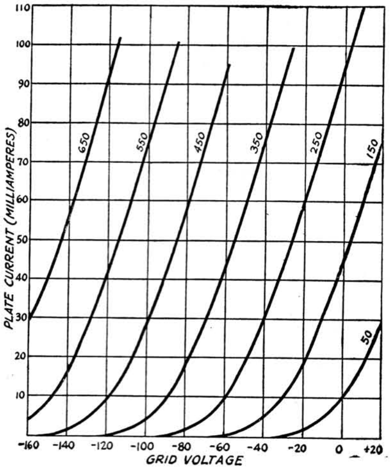

FIG. 7.—THE PLATE CURRENT IS PLOTTED AGAINST GRID VOLTAGE FOR THE UX-842 IN THIS FAMILY OF CURVES

The plate voltages at which the curves were made are indicated by the numbers near them.

Its constants under rated filament voltage, plate and grid voltage of 425 and minus 95 respectively are as follows:

Amplification factor	3.	
Plate resistance	2500.	ohms.
Mutual conductance	1.2	ma./v.

The direct inter-electrode capacities are:

Plate to grid	8. $\mu\mu$fd.
Grid to filament	5. $\mu\mu$fd.
Plate to filament	4. $\mu\mu$fd.

In Figs. 7, 8 and 9 we have similar curves for the 842 as are given in Figs. 1, 2 and 3 for the 841.

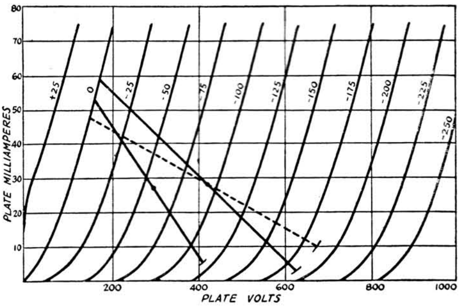

FIG. 8. — THE VERY IMPORTANT PLATE VOLTAGE-PLATE CURRENT FAMILY FOR THE 842

The grid voltage at which the curves were made are shown on them. The oblique dotted line is the preliminary load line drawn through the operating point and the 10-milliampere current point at twice the operating grid voltage. The distortion under these conditions was quite small and a lower limit of minimum plate current was chosen. The most suitable line for a plate voltage of 425 is the solid one passing through the same operating point as the dotted line. The other load line is for a plate voltage of 300.

As in the case of Fig. 3, Fig. 9 is based upon small input voltages and is not, therefore, applicable when the input is large.

When calculating the output power and proper load impedance, a resistance load is assumed as

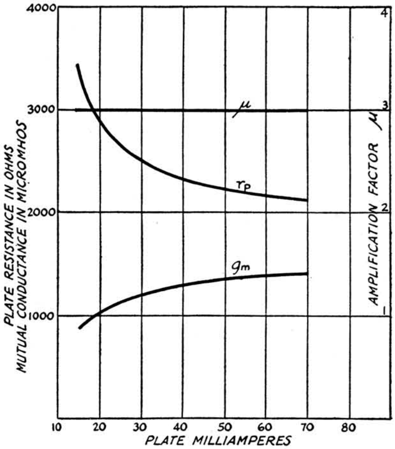

FIG. 9. — THE PLATE RESISTANCE, MUTUAL CONDUCTANCE AND AMPLIFICATION FACTOR ARE HERE PLOTTED AGAINST THE PLATE CURRENT FOR THE 842

this will result in a straight line for the load characteristic when this is laid out on the plate-voltage plate-current curves. If an impedance load were used, the characteristic would be an ellipse, its exact shape depending upon several factors.

If the plate voltage is to be 425, it is essential to choose a value of plate current which will result in a plate loss of 12 watts, the maximum allowable. This then, calls for a plate current of 28 milliamperes which Fig. 7 indicates may be obtained with a bias of 93 volts.

There are two limits within which one must stay to prevent distortion: The grid must not draw current and it is necessary to operate on the straight portions of the curves. Fig. 8 indicates that it would be inadvisable to go much below 10 milliamperes plate current as the curves become too badly curved to allow distortionless amplification below this value. If the filament of the tube is lighted with direct current, the grid will start to draw current at zero grid voltage. If, though, the filament is lighted by alternating current, it will not be possible to go to zero voltage but this point at which grid current is obtained will be approximately 4 volts negative.

Assuming d.c. on the filament, we find that the operating grid bias of 93 volts will allow a swing

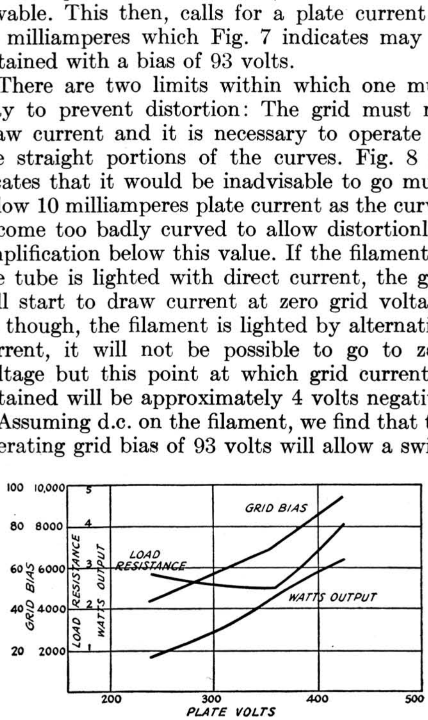

FIG. 10. — THESE CURVES GIVE THE PROPER GRID BIAS AND OPTIMUM LOAD RESISTANCE AS WELL AS THE OUTPUT FOR PLATE VOLTAGES BETWEEN 250 AND 425

At values above 360 volts, the plate dissipation is constant and the maximum allowable.

from 0 grid voltage to twice 93 or 186 volts. We judge the position of a curve for a grid voltage of 186 in Fig. 8 and set our lower plate current point on this curve at a value of 10 milliamperes which we had previously determined would be the probable lower limit for distortionless operation. A straight line is drawn from this point through the operating point and continued to the 0 grid-voltage curve. This line is shown dotted in Fig. 8. If now, we calculate the amount of second harmonic by means of Equation (1) we find that it is somewhat less than 1%. As our permissible value is 5%, we choose a lower minimum value of plate current and redraw our load characteristic line. If, in this particular case, we use a minimum plate current of 3 milliamperes, we will obtain the solid load line of Fig. 8 corresponding to our operating point of 28 mils and our calculations will show an harmonic content of approximately 5% which is the desirable operating condition.

The output power is then equivalent to:

Power output =

$$\tfrac{1}{8}\,(E_{max}-E_{min})\,(I_{max}-I_{min}) \qquad (2)$$

and the proper value of load resistance

Load resistance =

$$\frac{E_{max}-E_{min}}{I_{max}-I_{min}} \qquad (3)$$

In the case being considered we have:

Power output =

$\tfrac{1}{8}\,(628-176)\,(0.059-0.003)=3.16$ watts.

Load resistance =

$$\frac{628-176}{0.059-0.003}=8{,}060 \text{ ohms.}$$

Knowing that the power in watts is equal to the current squared times the resistance, we can obtain the value of a.c. current which is 19.8 mils.

When the plate voltage is low, the power output is not limited by the plate dissipation and the maximum power output is obtained when the load resistance is twice the plate resistance. A typical load line for a plate voltage of 300 is shown in Fig. 8.

In Fig. 10 we have curves showing the proper bias and load resistance for any plate voltage between 250 and 425. The maximum undistorted output power obtainable under these conditions

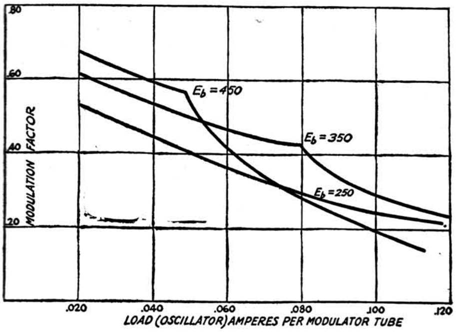

FIG. 11. — WHEN THE 842 IS EMPLOYED AS A PLATE MODULATOR, THE PERCENTAGE OF MODULATION CAN BE DIRECTLY OBTAINED IF THE MODULATED TUBE'S PLATE CURRENT IS KNOWN

This assumes a single plate supply for both tubes through a choke of infinite impedance and suitable bias and grid swing to the modulator tube.

may also be ascertained directly. For values of plate voltage below about 360, a plate load resistance of twice the plate resistance was chosen while for voltages above this value, use was made of the formulas (2) and (3).

MODULATOR

The 842 is well adapted for use as a plate modulator and Figs. 11 and 12 concern themselves with its use as such. These curves assume that the modulator and oscillator (or modulated amplifier tubes as the case may be) are operated from a single source of voltage which is fed through a modulation choke of infinite impedance over the frequency range desired. The total current to the oscillator and modulator will, therefore remain constant.

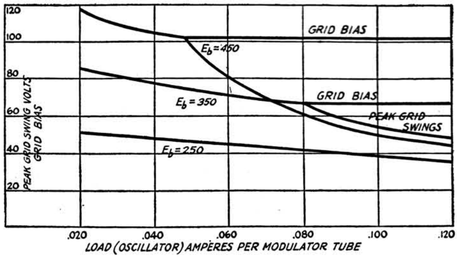

FIG. 12. — THE PROPER BIAS AND PEAK GRID SWING FOR THE MODULATOR WILL VARY WITH THE MODULATED TUBE'S PLATE CURRENT AND MAY BE OBTAINED FROM THE ABOVE CURVES WHICH ARE GIVEN FOR THREE VALUES OF PLATE VOLTAGE

Under these conditions, the oscillator plate resistance can be considered as being the load resistance for the modulator tube. Inasmuch as the load resistance has a considerable effect upon the output of the modulator, any change in the constants of the oscillator which reflects into the plate resistance of that tube will materially vary the percentage of modulation obtainable.

In this case when the load line is drawn in on the plate-voltage plate-current family, it is extended beyond the zero grid voltage curve to the zero plate voltage line. The value of current at which these intersect will be the total current supplied to the modulator and oscillator.

The percentage of modulation may be calculated:

$$M=\frac{E_{max}-E_{min}}{2E_o} \qquad (4)$$

where

M = Per cent modulation.

E_{max} = Plate voltage at highest grid voltage.

E_{min} = Plate voltage at lowest grid voltage.

E_o = Plate voltage at operating grid voltage.

When high oscillator currents are employed, the modulator current must be kept at a value that limits the plate dissipation to a safe figure. In order to locate the position of the load line, this point for maximum modulator plate current is connected to the point on the zero plate voltage line corresponding to the sum of this modulator plate current and the chosen oscillator plate current. The line is extended in the other direction to twice the operating grid potential. In this case the swing will be limited by the minimum plate current value.

Fig. 11 shows what values of modulation may be obtained when the plate current to the oscillator tube is varied over a wide range. These

(Continued on page 86)

Little-Known Tubes

(*Continued from page 29*)

values are contingent upon the operation of the modulator as indicated in Fig. 12 which gives the proper grid bias and maximum peak grid voltage usable.

When either 841 or 842 tubes are operated in parallel, a resistance of approximately 100 ohms should be placed as near to the grid of each tube as is practical. This will prevent the generation of parasitic high frequency oscillations between the tubes. If 841's are used as oscillators (842's should not be so employed) the resistors may be supplanted by suitable chokes which will have less effect upon the efficiency of the circuit. In all cases, the plate voltage should be reduced when a new circuit is being set in operation.

Financial Statement

BY order of the Board of Directors the following statement of the income and disbursements of the American Radio Relay League for the first quarter of 1929 is published for the information of the membership.

K. B. Warner, *Secretary.*

STATEMENT OF REVENUE AND EXPENSES FOR THE THREE MONTHS ENDED MARCH 31, 1929

REVENUE		
Advertising sales, *QST*.........	$16,938.05	
Newsdealer sales...............	13,831.88	
Advertising sales, handbook.....	2,382.23	
Handbook sales.................	5,799.89	
Dues and subscriptions.........	11,637.71	
Back numbers, etc..............	848.46	
Emblems........................	95.65	
Interest earned................	662.51	
Cash discounts earned..........	354.92	
Bad debts recovered............	125.22	$52,676.52
Deduct:		
Returns and allowances.........	$5,627.95	
Less portion charged to reserve for newsstand returns..	191.75	5,436.20
Discount 2% for cash..........	347.63	
Exchange and collection charges..	10.86	5,794.69
Net revenue..............		$46,881.83
EXPENSES		
Publication expenses, *QST*......	$14,203.53	
Publication expenses, Handbook..	3,679.11	
Salaries and commissions........	14,469.85	
Forwarding expenses............	773.07	
Telephone, telegraph and postage	1,097.78	
Office supplies and general expenses.....................	2,093.35	
Rent, light and heat...........	833.05	
Traveling expenses.............	1,004.28	
Depreciation of furniture and equipment.................	538.33	
Communications Department field expenses..................	63.57	
Headquarters Station expenses...	43.15	
Bad debts written off..........	300.00	
Total expenses............		39,099.07
Net gain from operations....		$7,782.76