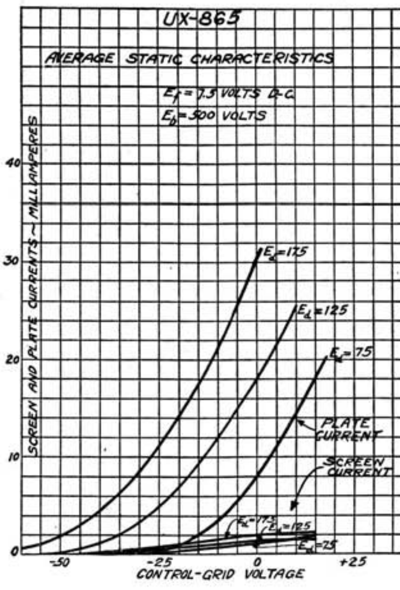
A New Low-Power Screen-Grid Transmitting Tube

By O. W. Pike *and* E. E. Spitzer*

THE UX-865 is a four-element tube of the screen-grid type designed primarily for use as a power amplifier in transmitting circuits. Under this condition, it has a nominal output rating of 7.5 watts and is especially adapted for use on the higher frequencies. The tube is also very useful as a crystal oscillator.

The electrode structure of the tube is built as a single unit, entirely supported from the bottom. The filament is of thoriated tungsten in the shape of a double helix supported from a center rod and



requiring no tension springs. All electrodes are cylindrical. The screen grid consists of a close mesh or winding mounted on side rods extending from a stem collar, and this forms the main supporting structure of the tube. The plate is suspended from this structure by glass beads. It has four fins for heat dissipation.

The function of the screen grid is to provide an electrostatic shield between the plate and the control grid. The voltage of the screen grid is held constant and variations in voltage of the plate have practically no effect on the control grid or on the electrostatic field at the filament. Therefore, there can be practically no feedback through the tube from the plate circuit. In radio-frequency amplifier circuits this eliminates the necessity for neutralization to prevent feedback and oscillation.

The bulb is mounted in a "UX" base. The plate lead is brought out through a cap on top of the bulb instead of through the plate pin in the base; the latter serves as the screen-grid terminal. The control grid and filament are brought out through the usual "UX" base pins.

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TECHNICAL DATA

The technical information on the UX-865, useful to the amateur, may be summarized as follows:

Main use . . . . Oscillator or r.f. power amplifier
Number of electrodes 4
Filament:
  Volts 7.5
  Amperes 2.0
  Type . . . . Thoriated Tungsten
Average characteristic values calculated at:
  $E_b = 500$, $E_c = 0$, $E_d = 125$, $E_f = 7.5$ a.c.
  E_b = Plate voltage.
  E_c = Control-grid voltage.
  E_d = Screen voltage.
  E_f = Filament voltage.

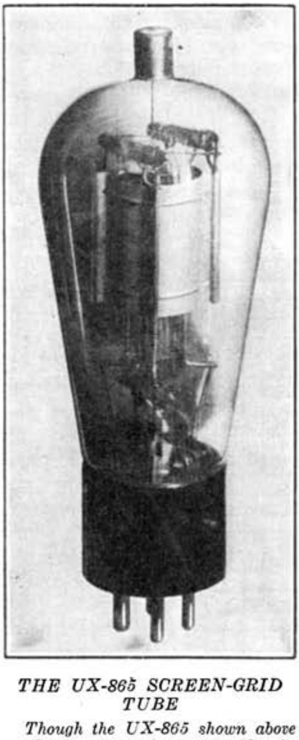
  Plate current . . . . .021 ampere
  Amplification factor 150
  Plate resistance . . . . 200,000 ohms
  Mutual conductance . . . . 750 microhms
Approximate direct interelectrode:
  Capacities (I.R.E.)
  Plate to grid (filament and screen grounded) 05 $\mu\mu$fd.
  Grid to filament and screen . . . . . 10. $\mu\mu$fd.
  Plate to filament and screen . . . . . 7.5 $\mu\mu$fd.
Maximum overall dimensions:
  Length . . . . 6 ¼″
  Diameter . . . . 2 3/16″
Base type . . . . UX and cap
Type of cooling . . . . Air
Oscillator and r.f. power amplifier.
Maximum operating plate volts:
  Modulated d.c. 500
  Unmodulated d.c. 500
  a.c. (r.m.s.) 500
  Maximum d c. plate current amperes .060
  Maximum plate-dissipation watts . . 15
  Maximum screen-dissipation watts . 3

Nominal screen-grid volts......... 125
Maximum r.f. Grid Amperes...... 5
Operation at Normal; $E_b=500$, $E_c=(-)75$, $E_d=125$, $E_f=7.5$
Output watts.................... 7.5

USE

When using the tube as an oscillator or radio-frequency amplifier, the plate dissipation should never exceed 15 watts, which produces no color on the plate. Regardless of the actual value of input and output, the efficiency should always be sufficient to limit the plate dissipation, that is, the difference between input and output, to this figure. The d.c. plate current should be held below 60 milliamperes. Without exceeding the dissipation or plate limits, it is possible by careful circuit adjustment to obtain an output of 10 watts of useful power at frequencies up to, and including, the 14,000-kc. amateur band. The 7.5-watt output figure is, therefore, conservative. The maximum plate voltage for modulated or non-modulated oscillator or r.f. power-amplifier service is 500 volts. If, for this service, a self-rectifying circuit is used, the value of a.c. plate voltage should never exceed 500 volts effective.

The screen voltage of approximately one-fourth the plate voltage may be obtained from a separate source or from the plate supply through a series resistance of approximately 20,000 ohms. The latter, or resistance method, is most desirable as it automatically maintains a proper screen-grid current. With the resistance method the filament circuit should not be opened with the plate voltage on, as this will place full plate voltage on the screen. With potentiometer or a separate source of screen voltage, the screen voltage should not be applied without the plate voltage. The screen need never dissipate much energy for proper functioning and no portion of it should be allowed to attain a temperature of more than a cherry red color. In all cases the external impedance between the screen and filament terminals must be kept as low as possible by the use of r.f. by-pass condensers. In any case, the screen dissipation must never exceed 3 watts at any time.



THE UX-865 SCREEN-GRID TUBE

Though the UX-865 shown above might be expected to resemble the smaller screen-grid tube and the 210, it really has but little in common with them. Unlike the UX-222, the metal cap at the top of the tube does not act as the terminal for the control-grid. It is connected to the plate and insures high insulation against leakage and voltage breakdown. The control-grid connects to the grid terminal of the standard "UX" base and the screen is connected to the regular plate pin.

Instead of finding an oval plate as in the 210, the plate of the 865 is round and provided with four fins to aid in the dissipation of heat. The plate is supported at the top by glass beads that are in turn supported by the four rods upon which the screen is wound. These are firmly attached to a clamp that encircles the stem.

Negative control-grid bias can be obtained from batteries or a gridleak and should have a value of about 75 volts. This value is not critical and can be varied to suit individual conditions. However, the use of less than 75 volts bias results in lower efficiency. A gridleak of 10,000 ohms will give approximately 75 volts bias. This requires a d.c. grid current of 7.4 milliamperes. If less excitation is available, a high-resistance gridleak can be used. The d.c. grid current, incidentally, is a very good indication of the amount of excitation. Grid currents between 5 and 10 milliamperes are sufficient to excite the tube to full output.

If the UX-865 is used as a straight amplifier (no frequency multiplication), the plate and grid circuits should be adequately shielded from each other to reduce any external coupling which may set the tube into oscillation.

When the tube is properly excited and shielded, it is excellently suited for driving the next largest screen-grid tube, the UX-860, or the corresponding three-element tube, the UX-852.

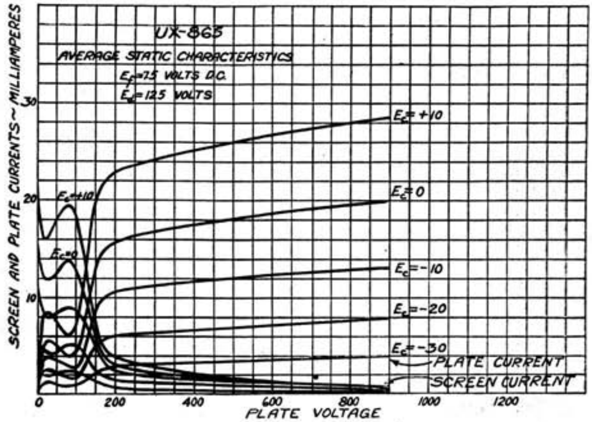
When using the UX-865 as a crystal oscillator, additional feedback external to the tube is generally necessary on account of the low grid-plate capacity. This is best accomplished by means of a small variable condenser connected from plate to control grid. About 10 $\mu\mu$ fd. maximum is sufficient in the 1750- and 3500-kc. amateur bands. It is best to connect a blocking condenser, which is insulated for the peak plate voltage, in series with the variable condenser, so that there is no danger of making a direct metallic connection between the grid and plate. By means of this feedback condenser, it is possible to adjust the load on the crystal very nicely and the danger of cracking the crystal by overloading is greatly lessened.

CHARACTERISTIC CURVES

The characteristic curves for the UX-865 which are shown here are included for the purpose of supplementing the information given in the preceding description of the tube.

When the tube is used as a radio-frequency power amplifier and, occasionally, for special reasons, as an oscillator, the grid- and plate-voltage swings are much larger than it is possible to show on a static characteristic curve. Therefore, these curves serve only to illustrate the peculiarities of screen-grid tubes in comparison with three-electrode tubes. In practice, the action of the UX-865 in power circuits is not greatly different from that of similar three-element tubes excepting for the elimination of the feedback capacity.

Fig. 1 shows values of plate current and screen current plotted against plate voltage for several



control-grid voltages and at a screen-grid voltage of 125. At the lower plate voltages, the plate current becomes very low due to secondary electron emission from the plate. The screen then draws electrons from both plate and filament, resulting in a screen current peak. As the plate voltage increases (with constant screen voltage) the plate current rises rapidly to its normal value while the screen current drops to a low value which in some cases becomes slightly negative due to secondary emission from the screen-grid. At its normal value, the plate current is practically constant although there is a slight increase because of imperfections in the screening as well as due to the secondary emission current drawn from the screen. In general, the slope of the plate-current curve in this region may be taken as a measure of the screening qualities of the tube.

Fig. 2 gives plate current and screen current plotted against grid voltage for three values of screen voltage and at the normal plate voltage. From these curves the mutual conductance may be calculated as with three-element tubes.

Notes on Distortion in Audio Frequency Amplifiers

(Continued from page 42)

Where the subscripts for Z, the external impedance, have the same significance as they have for a.

Equation 13 is the usual amplifier equation and will not be discussed here. F^2 is a function of internal and external impedances and the variations of the tube factors with input voltages. It will not be necessary to use the values of F for our purpose, so it will not be given here.

The plate current of frequency $2l/2\pi$ is given by $a_{2(2l)}A^2$. If we multiply this by $r_p+Z_{2(2l)}$, we obtain the second harmonic voltage introduced in the plate circuit. This voltage is

$$E_{(2l)} = FA^2 \tag{16}$$

Similarly we find the direct current voltage is

$$E_{(ol)} = FA^2 \tag{17}$$

As the second harmonic voltage is equal to the direct current voltage, we may find the second harmonic voltage by finding $E_{(ol)}$ introduced in the plate circuit. To do so it is only necessary to apply a voltage, $A \sin lt$, to the grid and note the change in direct current. The d.c. voltage introduced in the plate circuit is then $r_p+\overline{R}$, where $\overline{R}$ is the d.c. resistance of the plate load, times the change in direct current.

The voltage of frequency $l/2\pi$ is μA and the second harmonic voltage is equal to the d.c. voltage. The per cent distortion is then

$$\% \text{ distortion} = \frac{E_{2l}}{\mu A} \times 100. \tag{18}$$

Strays

In looking for a suitable form on which to wind a good radio frequency choke W7UJ came across the stand of an old "Kellogg" telephone. It was made of hard rubber, was 1¼" by 4½" and held 125 turns of 26 gauge d.c.c. wire. The resulting choke proved thoroughly satisfactory.

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"Hey YL, QRA?"

"Sa OM QRJ."

"Aw cum on LG QRD?"

"Say OM QRX or you'll wish you could QTA."

"Cum on be a sport QTU?"

"You're gonna have to QRS! QRZ?"

"First you'll have to tell me QTS?"

"Well OM if you must know your QTJ is too high, besides I'M QRL anyhow."

"Well QRY?"

"It's not a matter of QRM OM QRI so please QRT before I SOS and somebody gets QSR. QSE?"

"You don't have to QSH YL I'll QRP."

— *Ed Mace, ex W5EH.*