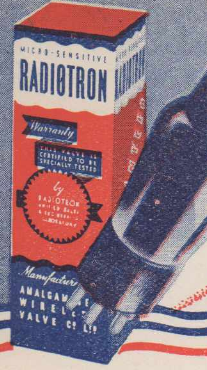
J. L. Dickey 5.11.36



RADIOTRONICS

AMALGAMATED WIRELESS VALVE COMPANY LIMITED

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In this Issue:

RADIOTRON 1K6
A Discussion on Reflex Operation

Reflex operation in A.C. radio receivers has been used for some years and no detailed discussion on the 6B7S as a reflex amplifier is necessary. In battery receivers reflex circuits have not been used to any extent, due largely to the absence of a valve suitable for this application. With the advent of the 1K6, reflex operation in battery receivers is now possible.

Sensitivity is not the only feature to be considered in reflex operation. Rectification in the amplifier, overloading, and special features in connection with the A.V.C. all need to be considered.

Rectification is caused through non-linearity of the characteristics and results in demodulation which is out-of-phase with the diode rectification. The degree of rectification is governed by the peak grid voltage (I.F. together with audio) and is quite small if the input is limited to that necessary for an output just sufficient to drive a 1D4 or similar type of valve. If the input is increased beyond a certain point overloading will occur with excessive rectification. On a signal which is not large enough to cause overloading certain effects will be found to occur as the volume control setting is increased. At the "zero" setting the output will not be zero due to this rectification, but the quality will be found to be quite good. As the volume control is increased the volume will at first decrease until (still at a very low output volume) minimum volume is reached, at which point distortion is very severe. As the control setting is further increased the volume increases and the distortion decreases to a normal level. The distortion at minimum volume is due to out-of-phase rectification and is unavoidable, but occurs at such a low level of output that it is not very apparent.

As the input to the reflex stage is increased it is found that *overloading* occurs at 0.5 volt (30% modulated) input with the volume control set at maximum. If the input is increased beyond this point motor-boating may occur while the rectification and distortion become severe. At this point the output from a 1D4 driven from the output of the reflex stage is 0.4 milliwatt due to the rectification in the amplifier.

If manual volume control is used there is no difficulty in avoiding overload on the reflex stage since a 1D4 is fully loaded when the input to the 1K6 grid is 0.04 volt. The circuit used in these measurements is shown in Fig. 1 which is not an exact replica of a practical radio circuit but is the nearest possible arrangement with regard to feeding a measured input. It is found that at this input voltage there is no measurable diode current with zero bias on the A.V.C. diode. This is due to the fact that there is an "internal" delay voltage in the 1K6 when the positive diode is returned to negative filament. The value of the delay is just sufficient to allow full output from the 1D4 on 30% modulation before the A.V.C. comes into operation.

When the input is increased to 0.5 volt the A.V.C. diode current is 6 microamp through 1 megohm and the D.C. voltage developed on the A.V.C. line is consequently 6 volts. This is the maximum voltage available for A.V.C. operation before overload commences.

It is, therefore, necessary, if A.V.C. is to be used, to design a system which limits the input to the 1K6 grid to 0.5 volts for the maximum aerial input signal which it is desired to receive without distortion. This means that a much more "sudden" A.V.C. action is required than in straight receivers.

With 1C4 and 1C6 valves, the lower the screen *supply* voltage, the sharper the A.V.C. action. This is shown in Fig. 3 for the 1C4. The curves give the mutual conductance in relation to screen voltage for two limiting bias voltages, zero and –6 volts. The mutual conductance is plotted on a logarithmic scale and it is, therefore, possible to measure ratios of mutual conductance by sliding a logarithmic scale vertically on the diagram so as to measure the difference between the curves. An alternative arrangement is to measure the vertical distance between the curves by marking a piece of paper and then transferring the marked length to the logarithmic scale at the side of the diagram.

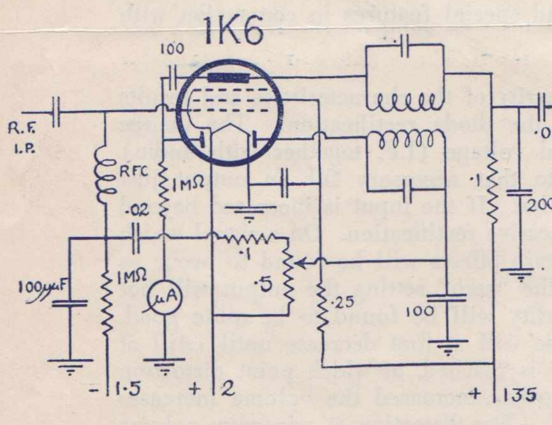


Fig. 1

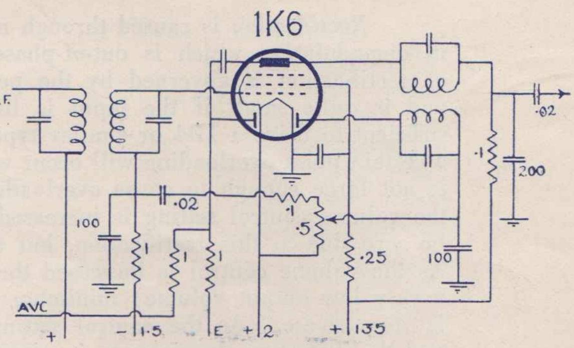


Fig. 2

RECEIVER DESIGN

Several circuit arrangements can be used with reflex operation and three of the possible arrangements will be examined with relation to A.V.C. action.

1. 5 valve 1C4 (RF) 1C6 (Con.) 1C4 (I.F.) 1K6 (reflex) 1D4 (output).
2. 4 valve 1C4 (RF) 1C6 (Con.) 1K6 (reflex) 1D4 (output).
3. 4 valve 1C6 (Con.) 1C4 (I.F.) 1K6 (reflex) 1D4 (output).

No. 1 arrangement has so much available sensitivity that an extremely good A.V.C. system is necessary. For 50 mW output the grid input to the 1K6 reflex will be

$$\sqrt{\frac{50}{350}} \times .04 = 0.105 \text{ volt}$$

The limiting voltages on the grid of the 1K6 are therefore 0.015 to 0.5 volt. If it is assumed that the receiver should be capable of handling an aerial input voltage of 0.1 volt the conditions will be as shown in the table.

Receiver sensitivity (input) for 50 mW absolute output	1	5	25 microvolts
Gain from aerial to 1K6 grid:—			
(a) At zero bias	15000	3000	600 ,,
(b) At −6 bias	5	5	5 ,,
Ratio of gain per stage with 2 controlled stages	55	24.5	11 ,,
Maximum screen supply voltage on 1C4 valves	24.5	40	67.5 volts

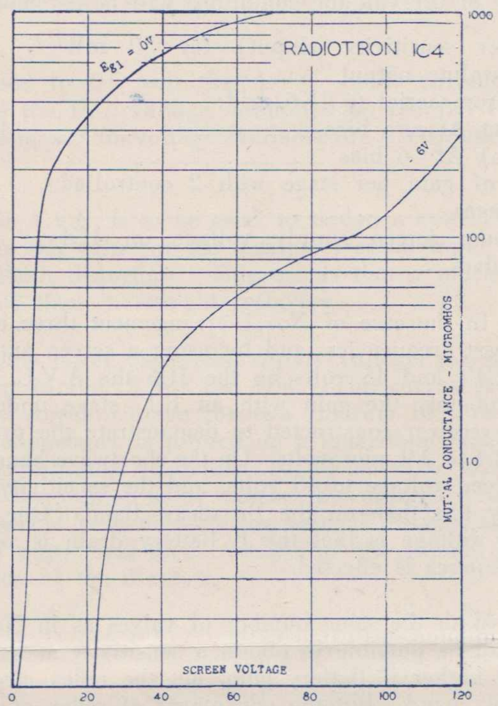
In the case of No. 1 arrangement three controlled stages may be used on broadcast frequencies, and by using a screen supply voltage of 22.5 volts on the two 1C4's and 45 volts on the 1C6 the A.V.C. requirements should be satisfied. Unfortunately the gain with an R.F. stage under these conditions is rather low and a receiver constructed to demonstrate the principle only gave a sensitivity of from 2.4 to 2.9 microvolts. On the shortwave band it was found possible to increase the screen voltage to 45 volts, and the sensitivity under these conditions was only slightly less than on the Broadcast Band. One advantage of such a low screen supply voltage is that the B Battery drain is very low, and a saving of several milliamperes is effected.

With the same number of valves as in No. 1, but without reflex operation it would be possible to obtain a sensitivity at least as good on the B.C. Band but with a higher B Battery gain, but the reflex circuit would show to advantage on the S.W. band. But the advantages of reflex operation are more definite with the smaller number of valves.

With arrangements Nos. 2 and 3 there are only two controlled stages of which one (the 1C6) is only partially effective due to the higher screen voltage which is necessary. This disability is partly offset by the decreased sensitivity, and it has been found possible to construct a receiver of this class which could be classed as satisfactory. Since most of the A.V.C. action must occur in the 1C4, the screen voltage will need to be limited to 22.5 volts. As an R.F. amplifier the stage gain will be less than as an I.F. amplifier and arrangement No. 3 will probably be preferred.

When reflex operation is used a certain amount of regeneration is inevitable, some being due to valve capacities and some to stray wiring capacities. If an additional I.F. stage is used this regeneration is of greater importance due to the higher amplification at intermediate frequency. Chassis layout and wiring are critical and a cramped layout may cause serious difficulty. If two I.F. stages are used there is no need for high-gain I.F. transformers and solid copper air-core transformers have given extremely high gain. A receiver using such I.F. transformers with the addition of an R.F. stage gave a bandwidth of 38 K.C. for 1000:1 ratio. A sensitivity of about 8 microvolts (absolute) would be a reasonable figure for arrangement No. 3 with 4 valves, but the actual sensitivity depends very largely on the amount of regeneration. In order to demonstrate the possibilities of high gain I.F. transformers a 4 valve reflex circuit was built (Arrangement No. 2) and gave a sensitivity of 1.0 microvolt absolute. This receiver could not be regarded as a commercial proposition, but the example serves to show the extreme sensitivity which can be obtained with individual care.

Fig. 3



SUMMARY.

With all reflex arrangements the audio distortion due to the reflex stage is fairly high, and it is therefore not to be recommended for quality receivers. For receivers less than 5 valves the use of reflex appears to be worth serious consideration, but it is put forward as an interesting possibility rather than as a recommendation. Figure 2 shows the suggested arrangement of the reflex stage itself and this may be incorporated in a suitable circuit. It is suggested that no modifications should be made to the diagram unless complete performance data, including audio distortion, is obtained.

RESISTANCE COUPLED PENTODES
DYNAMIC CURVES

Questions are frequently asked regarding the correct constants to use with resistance coupling; what screen voltage, grid bias voltage, cathode bias resistor? The whole matter has been investigated in the Laboratory of Amalgamated Wireless Valve Company Limited and a number of interesting conclusions have been reached. It is not generally realised that with pentodes there is no one particular set of conditions which must be used for the best results. The family of dynamic curves shown for Radiotron 6C6 Pentode illustrates the similarity between them. For any screen voltage between 20 and 100 volts the curve is of almost the same shape, but is displaced to the left as the screen voltage is increased. Consequently any screen voltage between 20 and 100 volts may be used provided that the control grid is biased to suit.

This family of dynamic curves refers to type 6C6 Pentode with a plate supply 250 volts and a load resistance of 0.25 megohm. The plate current under these conditions can never quite reach 1.0 milliamp. unless the valve is short circuited. Each curve is situated between the zero current line and the 1.0 milliamp. limit, and consists of a curved portion at each end and a straight portion in the middle. In order to avoid distortion it is necessary to work on the straight portion. Measurement shows that the lower screen voltages give a longer straight portion of the curve than is given by higher voltages.

Since Ohms Law holds in the plate resistor, the plate current may be used as a measure of plate voltage. Obviously when no plate current is flowing there is no voltage drop in the plate resistor and the full voltage (250 volts) is on the plate. At the other extreme, when the valve is shortcircuited from plate to cathode there is no voltage difference between plate and cathode and consequently the plate voltage is zero, all the voltage drop occurring in the plate load resistor. It will be seen that on the diagram 1MA plate current is also marked zero plate voltage, and zero plate current is marked 250 plate volts.

An inspection of the curves shows that for most screen voltages the centre of the straight portion occurs at 0.56 milliamp. The first step in the adjustment for minimum distortion is therefore to adjust screen and control grid voltages until the plate current is 0.56 milliamp.

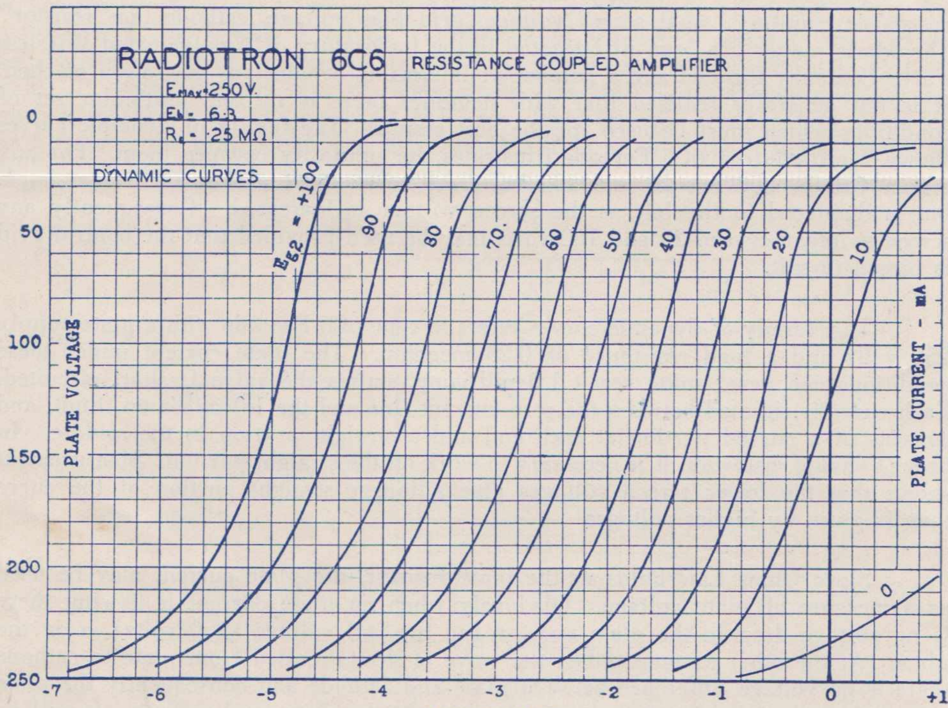
Grid current may commence at –0.7 volts and the working region of the curves must be to the left of this point. The lowest screen voltage curve whose straight portion is wholly within the no-grid-current region is that for 30 volts. It is preferable for several reasons to use a fairly low screen voltage, and from 30 to 40 volts is recommended.

It is obvious that if conditions are determined for any particular screen voltage these conditions can be modified quite simply by an adjustment of grid voltage so that they apply to any other screen voltage. For example, working at the recommended plate current (0.56 m.A.) a bias of –4.9 volts is necessary for a screen voltage of 100 and a bias of –1.1 volts is necessary for a screen voltage of 30. Other values than these remain practically unchanged.

CALCULATIONS MADE FROM STATIC CHARACTERISTICS.

If dynamic curves are not available for the particular valve or conditions being considered it is possible to obtain similar results from the static plate current plate voltage curves for any screen voltage. Figure 2 shows these curves for Radiotron

Fig. 1



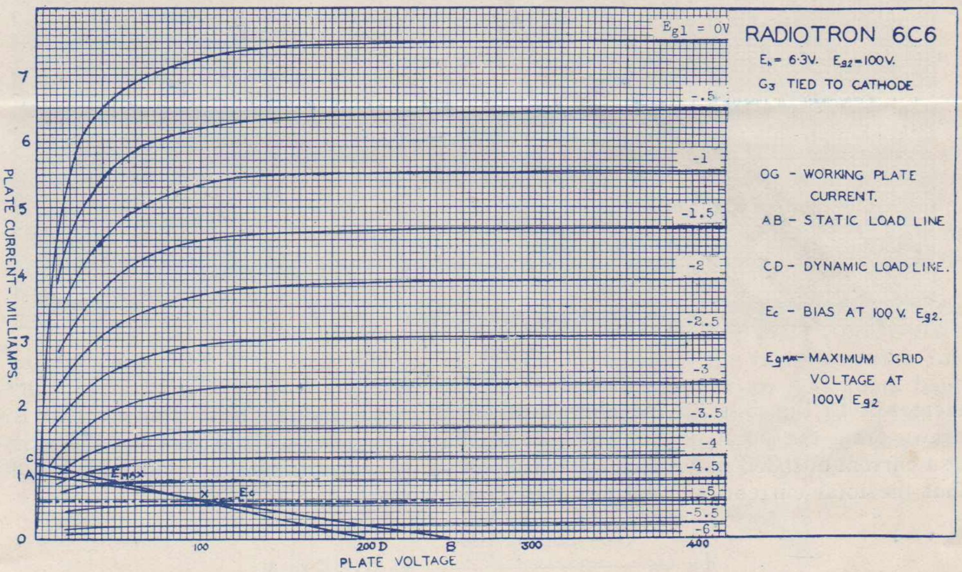
6C6 with a screen voltage of 100. In this diagram the line AB refers to a plate supply voltage of 250 and 0.25 megohm load resistance. The dynamic load line, CXD, is drawn for conditions with a 1 megohm grid resistor for the following valve, the A.C. load impedance (0.2 megohm) being given by the two loads of 0.25 and 1 megohm in parallel. From these values taken at 100 volts on the screen similar values can be derived to apply to any other convenient screen voltage.

Figure 2 shows that the optimum bias for 100 volts on the screen is –4.9 volts and that the grid swing extends to –4.5 volts before non-linearity occurs. The peak grid amplitude is therefore 0.4 volts under these conditions. The working plate current is 0.56 m.A. and the upper linear limit of plate current is 0.9 m.A. These agree with the results obtained from Figure 1. In order to apply these calculations to other screen voltages it is necessary to use the "triode" curves for the valve under consideration. These are the curves for total cathode current of the valve with equal plate and screen voltages.

With high plate resistance pentodes such as the 6C6, the plate current remains very nearly constant, even for considerable changes of plate voltage, provided that the screen and control grid voltages remain constant. The "triode" curves of the 6C6 may therefore be regarded with fair accuracy as the curves of total cathode current with any plate voltage. These are shown in Fig. 3.

Another property of these valves is that the ratio of plate to screen currents remains practically constant under all linear working conditions. In the 6C6 this ratio of plate to screen currents is 4 to 1. If the plate current is to be adjusted to 0.56 m.A. and the screen current is $\frac{1}{4}$ of the plate current its value will be 0.56 divided by 4 = 0.14 m.A. The total plate plus screen current is, therefore, 0.70 m.A.

Fig. 2



In Figure 3 this total cathode current is plotted against equal plate and screen voltage. As previously explained, we may regard these as referring to screen voltage only and applying to any plate voltage, the error due to this assumption being always less than 5% for the valve types under consideration.

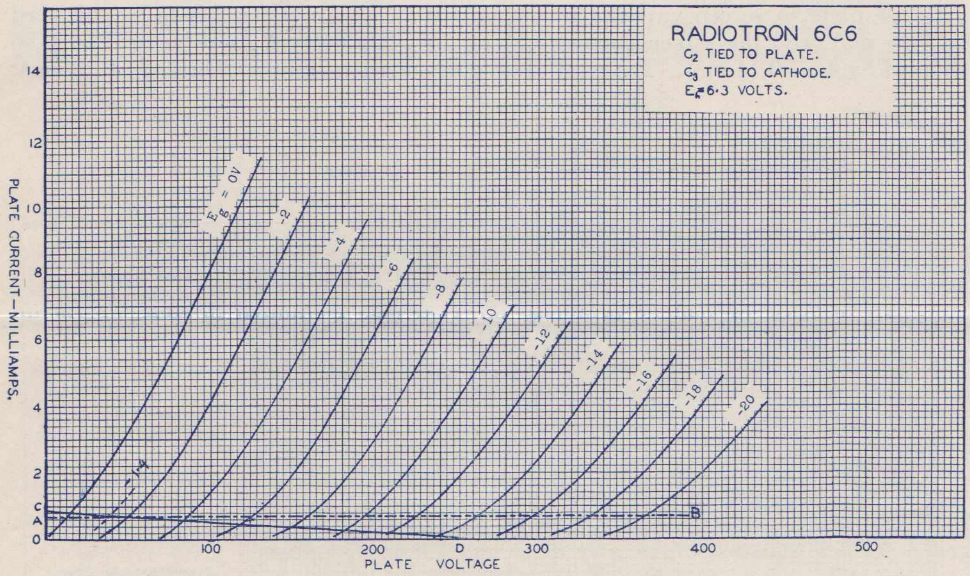
The minimum working bias is equal to the sum of the voltage at which grid current commences and the peak grid voltage amplitude.

$$E.g. = -(0.7 + 0.4) = -1.1 \text{ volt.}$$

On the "triode" curves of the 6C6 the "plate" voltage (which in this case is the actual screen voltage) corresponding to 0.7 m.A. total cathode current and –1.1 volts bias is 30 volts. This is the minimum screen voltage which can be used for full voltage swing.

The screen supply may be obtained through a dropping resistor from 250 volts supply. This can be calculated from the known screen voltage and current, but it can also be obtained graphically from the "triode" curves. The screen dropping resistor for 30 volts screen and –1.1 volts bias is 1.6 megohms, but this is not a convenient size. If 1.5 megohms is used the screen voltage and bias will need to

Fig. 3



increase. In Fig. 3 a 1.5 megohm "equivalent" load line has been drawn. This is drawn from the point of 250 volts, zero current, to intersect the zero voltage axis at a current of 0.833 m.A. This latter current value is determined from the knowledge that the total current is five times the screen current.

$$I_K = \frac{5 \times 250 \times 1000}{1500000} = 0.833 \text{ m.A.}$$

This 1.5 megohm "equivalent screen load line" cuts the 0.7 m.A. current line at a grid bias of –1.4 volts which when referred to the voltage axis gives a voltage of 37.5 volts effective on the screen.

The revised operating conditions for 1.5 megohm screen dropping resistor are therefore:—

Plate supply	250 volts.
Screen supply	250 volts.
Screen dropping resistor	1.5 megohms.
Plate current	0.56 m.A.
Screen current	0.14 m.A.
Total cathode current	0.70 m.A.
Grid bias	–1.4 volts.

The cathode bias resistor will be

$$R = \frac{1.4 \times 1000}{0.7} = 2000 \text{ ohms.}$$

Since this is a convenient size, no further adjustment is necessary.

SCREEN DROPPING RESISTOR.

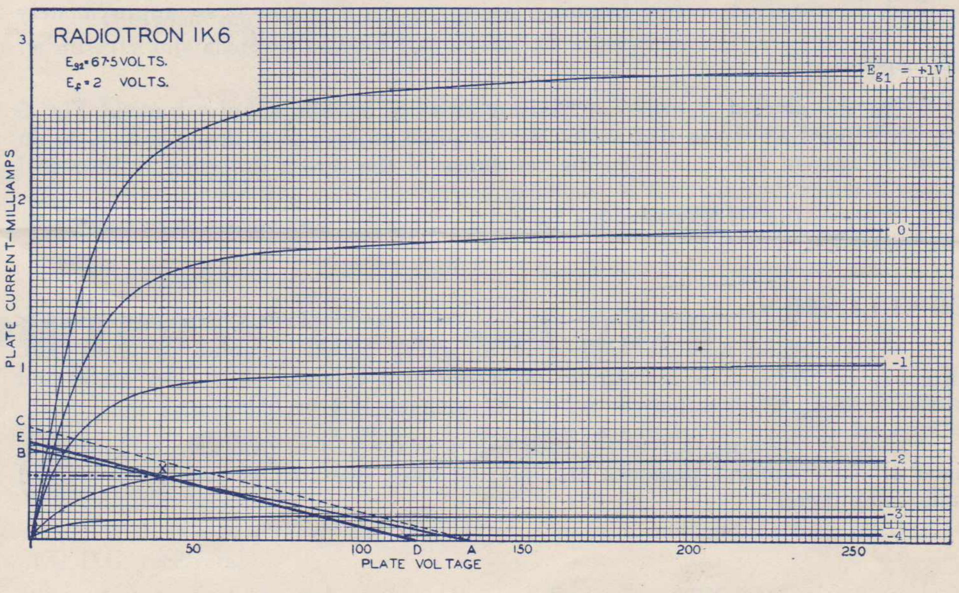
Numerous examples could be given of calculations of operating conditions for resistances coupled pentodes. In all cases it is necessary to commence with the assumption of certain values. It is generally preferred to assume the plate load resistor (0.25 megohms is recommended for general application) and then either the screen voltage or cathode bias resistor may be assumed and the remaining unknown quality calculated. Since it is necessary in the case of self-bias to choose a bias resistor of convenient resistance this may be taken as the first step and the screen voltage and dropping resistor calculated from it, or vice versa.

1K6 PENTODE.

In the case of battery pentodes, the grid bias is limited to steps of 1.5 or 2 volts if battery grid bias is used. Fortunately in the case of resistance coupled pentodes this presents no difficulty as the screen resistor may be proportioned to adjust the working point. As an example, take the 1K6 pentode as a resistance coupled audio amplifier with –1.5 volts bias. The plate voltage is to be 135 volts, plate load 0.25 megohm and the grid leak of the following valve to be 1 megohm. It is required to find the screen dropping resistor to use if the screen supply is to be obtaind from either 135 volts or 67.5 volts.

First plot the static .25 megohm load line on the pentode plate voltage-plate current curves for Radiotron 1K6, as in Fig. 4. Next draw the dynamic curve for the plate load of 0.25 and 1 megohm in parallel. That is, for an A.C. plate load of 0.2 megohm. With a ruler and set square search on the static line for the optimum dynamic line such that is intersects the static line in the centre of its linear portion. The point of intersection occurs at the working plate current of 0.39 m.A.

Fig. 4



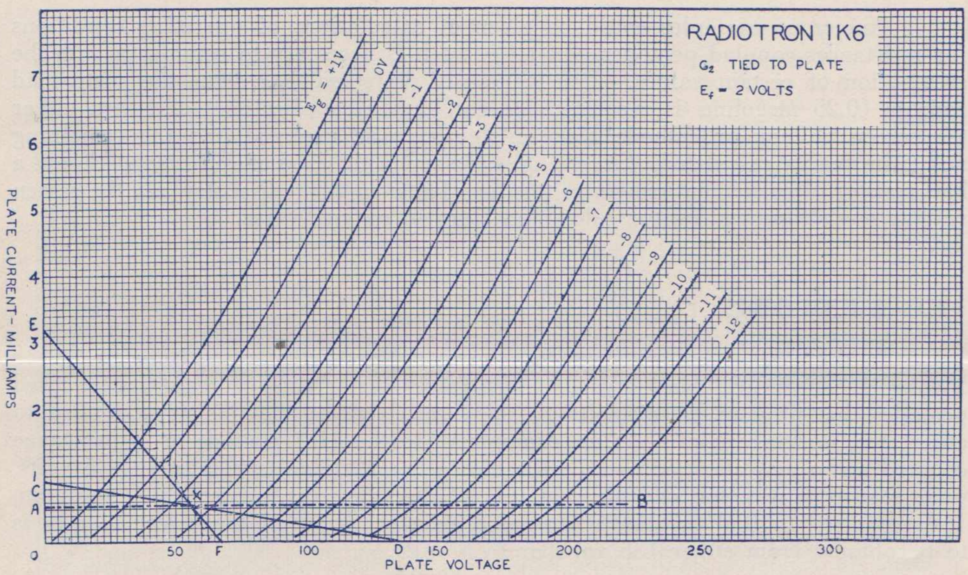


Fig. 5

From the characteristics we find that the ratio of screen to plate current is $\frac{1}{3}$. The screen current is, therefore, 0.13 m.A., the total cathode current 0.52 m.A. and the ratio of screen current to total cathode current $\frac{1}{4}$. Plotting this value of total cathode current on the triode curve of Fig. 5 gives the line A-B. The point X at –1.5 volts bias is the working point. Drawing through X the load line CXD we find the required screen dropping resistor to be $4 \times \frac{OD}{OC}$ = approximately 0.6 megohm.

In the case of a dropping resistor from 67.5 volts supply draw in Fig. 5 the load line EXF from 67.5 volts on the plate voltage axis through X to E on the plate current axis, and then the resistance of the screen dropping resistor will be $4 \times \frac{OF}{OE}$, that is 85,000 ohms.

CONCLUSION.

This method may be applied to all sharp cut-off pentodes of types 6C6, 1K6, 57, 77, 6J7, but is inaccurate for screen grid valves such as 24A or 32 and is also inaccurate for super-control valves such as 1C4 or 6D6.

Triode operating curves for such valves as the 1C4 or 6D6 are not published, since all super-control pentodes are inferior when operated as resistance coupled audio amplifiers.

The methods described will be found applicable to all types of pentode valves which are satisfactory for use as resistance coupled amplifiers.

RECOMMENDED OPERATING CONDITIONS FOR RADIOTRON 6C6.

Plate supply voltage	250 volts.
Screen supply voltage	250 volts.
Screen dropping resistor	1.5 megohm.
Cathode bias resistor	2000 ohms.
Grid bias	–1.4 volts.
Plate current	0.56 m.A.
Screen current	0.14 m.A.
Stage Gain for small input voltage	120
Peak voltage output for negligible distortion	80 volts.
RMS voltage output for negligible distortion	57 volts.
Maximum Peak Output (6% distortion)	100 volts.
Maximum RMS Output (6% distortion)	70 volts.
Grid Resistor of following valve	1 megohm.

RADIOTRON 6G5 "Magic Eye"

The 6G5 is identical with the 6E5 except for the remote cut-off grid characteristic which allows a larger signal input without overlapping of the fluorescent screen. With 250 volts supply, cut-off occurs at –22 volts as compared to –8 volts for the 6E5 under similar conditions.

The plate and target currents of the two valves are identical, and they can be directly interchanged without any circuit adjustment whatever.

There are a few special applications where the sharp cut-off characteristics of the 6E5 are desirable, but in most cases the 6G5 will probably be preferred.

An article dealing with application problems of the 6E5 and 6G5 will appear in Radiotronics Technical Bulletin No. 70 to be published on 25th November, 1936.

RADIOTRONS 25Z5 and 25Z6

New ratings have been given for Radiotron 25Z5 with 100 ohms resistance directly in series with each plate. Under these conditions the maximum applied voltage is 250 volts A.C. or D.C. and the maximum rectified current with the two halves connected in parallel is 85 milliamps.

With this new rating the 25Z5 appears to be a most satisfactory rectifier for A.C.-D.C. receivers.

Similar ratings apply to the all-metal Radiotron 25Z6.

RADIOTRON 6B8 (Duo Diode Pentode)

This new all-metal Radiotron is the equivalent to the 6B7 in the glass series. The characteristics of the two valves are not quite identical, and the 6B8 has a higher mutual conductance than the 6B7, but the two are sufficiently close to one another to be regarded as equivalents.

(TENTATIVE DATA)

Heater Voltage (A.C. or D.C.)	6.3	Volts.
Heater Current	0.3	Ampere.
Direct Interelectrode Capacitances — Pentode Unit:		
Grid to Plate (with shell connected to cathode)	0.005 max.	uuf.
Input	6	uuf.
Output	9	uuf.
Maximum Overall Length	$3\frac{1}{8}$".	
Maximum Diameter	$1\frac{5}{16}$".	
Cap	Miniature.	
Base	Small Octal 8-Pin.	

PENTODE UNIT: CLASS A AMPLIFIER.

Plate Voltage	250 max.	Volts.
Screen Voltage	125 max.	Volts.
Grid Voltage	–3	Volts.
Plate Current	10	Milliamperes.
Screen Current	2.3	Milliamperes.
Plate Resistance	0.6 approx.	Megohm.
Amplification Factor	800 approx.	
Mutual Conductance	1325	Micromhos.
Grid-Bias Voltage *	–21 approx.	Volts.

* For cathode current cut-off.

DIODE UNITS.

Two diode plates are placed around a cathode, the sleeve of which is common to the pentode unit. Each diode plate has its own base pin.

PIN CONNECTIONS.

Pin 1—Shell	Pin 6—Screen
Pin 2—Heater	Pin 7—Heater
Pin 3—Plate	Pin 8—Cathode
Pin 4—Diode Plate	Cap —Grid
Pin 5—Diode Plate	

(Pin numbers are according to RMA System)