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RCA RADIOTRON
D I V I S I O N

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APPLICATION NOTE
ON
SIGNIFICANCE OF RATINGS FOR POWER OUTPUT TUBES

Maximum ratings for each type of power output tube are established on the basis of life tests and operating performance. Experience indicates that when one or more maximum ratings are exceeded for an appreciable time, the serviceability of a tube type may be impaired--life may be shortened, or performance may be unsatisfactory. It is the purpose of this Note to discuss the significance of output tube ratings, to show how certain maximum ratings may be unintentionally exceeded in practice, and to suggest means for reducing the possibility of exceeding maximum ratings.

Significance of the Word "Maximum"

A voltage, current, power, or resistance value which is followed by the word "maximum" should not be exceeded for an appreciable time under steady-state conditions. In an output tube, for example, a plate potential of "250 volts maximum" signifies the recommended maximum d-c voltage which may be applied between plate and cathode under steady-state conditions. The instantaneous value of plate potential may vary from zero to 500 volts during operation, but it is necessary that the plate potential indicated by a d-c meter not exceed 250 volts.

Frequency and wave form of the alternating plate potential may be important. Thus, in a d-c amplifier, the frequency and wave form of the applied signal may be such that the instantaneous plate potential remains at 500 volts for an appreciable time. Maximum ratings for output tubes do not hold for such unusual applications; maximum ratings obtain only for operation in normal radio-receiving circuits.

Heater Rating

Heater or filament voltage is given as a normal (rated) value unless otherwise stated. In a radio receiver, apply rated heater voltage to the tubes under average line-voltage conditions; experience indicates that a good average value of line voltage is 117 volts (rms). The design of heaters is such that a rise in line voltage to 125 volts does not seri-

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ously reduce tube life. The values of average and maximum line voltages used in this Note are those recommended by the Radio Manufacturers Association.

Some tube types have a maximum heater-voltage rating. These types are not recommended for use in applications where the maximum heater-voltage rating is exceeded for an appreciable time during normal operation. Thus, the voltage of a battery in an automobile may rise to 8 volts; a tube type which has a maximum heater-voltage rating of 7 volts is not recommended for use in an auto-radio receiver.

An important effect of operating a heater above its maximum rating for an appreciable time is that tube life is reduced. Excess heater voltage may also cause the temperature of other elements in the tube to rise to abnormally high values. When the control grid of a tube is overheated, for example, it may emit electrons, which are attracted to screen and plate. The current due to these electrons flows through plate, screen, and control-grid circuits. When the resistance in series with the grid circuit is high, the voltage drop in the grid-circuit resistance due to grid-emission current is high and the polarity of this voltage is such as to oppose the normal negative bias on the tube. This condition is illustrated in the circuit of Fig. 1.

The loss in bias due to grid emission causes high plate and screen currents, which increase the temperature of plate and screen. When the temperature of plate or screen becomes high enough, occluded gas is driven from the elements of the tube; this gas is ionized by electron bombardment. Positive gas ions then bombard the cathode. Positive ion bombardment of the cathode causes loss in active emitting area of the cathode and increased cathode temperature. The effects are usually cumulative; the action continues until emission from the cathode falls to a very low value. It is seen from this brief explanation that two precautions may be taken to reduce the effects of possible grid emission: (1) do not exceed the maximum recommended value of d-c resistance in the grid circuit and (2) do not exceed the recommended maximum value of heater voltage for an appreciable time.

Recommended Grid Bias

A value of grid bias is established for given operating conditions to permit of the most satisfactory operating performance. Insufficient grid bias may cause distorted reception and possible injury to the tube because of high plate and screen current. Excessive grid bias will reduce sensitivity and in many cases increase distortion. Excessive plate and screen dissipation may injure a tube by driving occluded gas from the tube structure. Ionization of gas in a tube may ruin its cathode, as previously described.

A maximum value of grid resistor is usually specified. These maximum values limit the effects of grid emission and gas current. Gas current produces the same effects as grid emission. A negatively biased grid attracts positive gas ions; the direction of flow of these gas ions is such as to reduce the grid bias by an amount equal to the voltage drop across the grid resistor. Thus, it is necessary to limit the resistance value of a grid resistor to insure good tube life.

The recommended maximum value of grid resistance is higher for self-biased operation than for fixed-bias operation. A difference is permissible because a loss in bias due to gas or grid-emission effects is nearly counterbalanced by an increase in voltage across the self-bias resistor.

Screen Ratings

Maximum voltage, current, and dissipation ratings may be specified for a screen grid. The maximum-voltage rating is the highest value of d-c voltage that may be applied between screen and cathode. When the screen voltage is higher than maximum, screen dissipation may become excessive. Excessive screen dissipation, in turn, may cause electron emission from the screen or high gas current; the undesirable effects of gas and grid emission have been discussed previously.

A maximum screen-current rating may be specified in order to fix a value of screen dissipation. A screen-current rating is necessary, because more than rated screen current may flow when normal screen voltage is applied. For example, normal plate current of a tube may be 100 ma. and normal screen current may be 5 ma. for certain voltage conditions. If the plate voltage is removed, the screen current may rise to 80 or 90 ma., even though screen voltage and control-grid bias are normal. It is for this reason that plate voltage should not be removed from a screen-grid tube while screen voltage is applied.

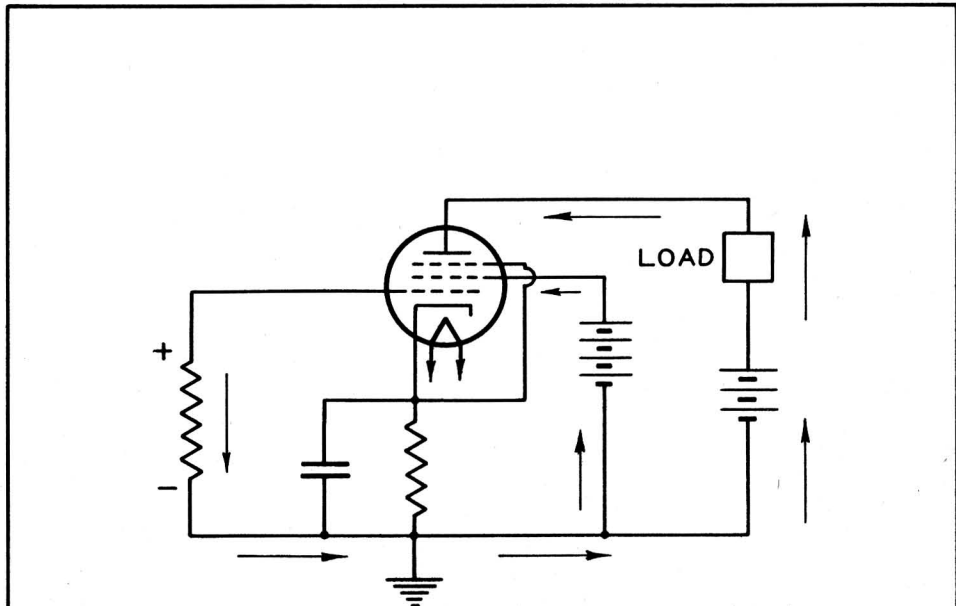
The rise in screen current with signal is important in many cases. This rise in d-c screen current is due to the effect of the plate voltage in influencing the value of screen current. This effect may be explained with the aid of Fig. 2.

A zero-bias plate and screen characteristic is shown for a typical pentode. With load line (1) and an applied signal great enough to swing to zero bias, the minimum instantaneous plate potential is e_1 and the peak value of screen current is i_1 . With a much smaller load (2), the minimum instantaneous plate potential is e_2 and the peak value of screen current is i_2 . Because the value of d-c screen current depends on the maximum instantaneous value of the general symbol, i , the screen dissipation may exceed the recommended maximum value at full output when a high value of load is used. Thus, the practice of choosing a load on the basis of highest power output at acceptable distortion should be supplemented by measurements of screen current. It may be necessary to sacrifice power output in order to operate the tube within the maximum ratings. Maximum screen-voltage rating should not be exceeded when the line voltage is reasonably high; experience indicates that maximum screen-voltage rating should not be exceeded when the line voltage is 125 volts (rms) or more.

Plate Ratings

Maximum plate-voltage, plate-current, and plate-dissipation ratings for each tube type are usually specified. An important effect of exceeding recommended maximum plate ratings is to shorten tube life; the reasons for short life under these conditions are similar to those given under "Screen Ratings."

Zero-output and full-output plate and screen conditions may be illustrated by an example. Consider two 6L6's operating in push-pull with 400 volts applied to the plates and 300 volts applied to the screens. At zero output, plate current for two tubes is 102 ma. and plate dissipation is $400 \times 0.102 = 40.8$ watts (two tubes); zero-output screen dissipation is $300 \times 0.006 = 1.8$ watts. At full output, plate current for two tubes is 230 ma. and power output is 60 watts; plate dissipation is, therefore, $400 \times 0.230 - 60 = 92 - 60 = 32$ watts (two tubes). Screen current at full output is 20 ma. (two tubes), and screen dissipation is $300 \times 0.02 = 6$ watts (two tubes). Thus, screen dissipation increases from 1.8 to 6 watts and plate dissipation decreases from 40.8 to 32 watts as power output increases from zero to 60 watts. Experience indicates that maximum plate ratings should not be exceeded when the line voltage is 125 volts or higher.



ARROWS INDICATE DIRECTION OF CURRENT FLOW DUE TO GRID EMISSION OR GAS.

FIG. 1

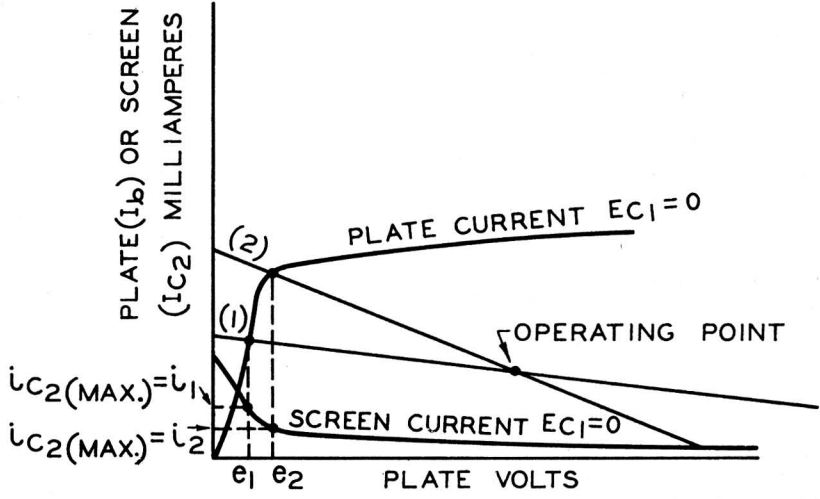


FIG. 2

The license extended to the purchaser of tubes appears in the License Notice accompanying them. Information contained herein is furnished without assuming any obligations.