# New 100-Milliampere Tubes for 120-Volt Series-Heater-String Home Radio Receivers

This Note describes a group of tubes for series-string applications in either five-tube or four-tube home radio receivers. Complements of these tubes operate at a total rated heater voltage of 120 volts and require a heater current of only 100 milliamperes. The performance of these new tubes in typical receivers is compared with conventional complements operating at a total heater voltage of 117 volts and a heater current of 150 milliamperes. In addition, the Note describes and evaluates an experimental four-tube economy receiver using the new 100-milliampere tubes.

## Advantages of 120-Volt, 100-Milliampere Tube Complements

Recent studies indicate that the average outlet voltage in the United States is about 117 volts. However, the number of homes having higher outlet voltages is increasing as a result primarily of better wiring systems and better primary-voltage regulation. Extensive tests have shown that the failure rate of electron tubes is considerably higher if they are operated at excessive heater voltage than if they are operated at slightly reduced heater voltage. Because these tubes are designed to operate at a line voltage of 120 volts, operation at slightly lower line voltage is expected to result in some improvement in tube life.

The reduction in heater power achieved by use of a 120-volt, 100-milliampere complement decreases the temperature of the hottest spots on the tops of the cabinets tested from 15 to 25 per cent. As a result, it is possible to design smaller cabinets or to obtain improved acoustic performance by reducing the number of ventilating holes. This heat reduction also lends new flexibility to the positioning of parts and printed-circuit boards, and reduces the possibility of cabinets warping or changing color.

Heater-power surges that occur when a radio is switched on are lower with the 120-volt complement because the cold resistance of the 100-milliampere heater is inherently higher and tends to reduce the current surge. More even distribution of heater voltages in the 100-milliampere complement also tends to reduce the magnitude of the initial voltage surges across the 18- and 20-volt tubes. For example, the heater-surge voltage for the 12.6-volt tubes in the five-tube, 150-milliampere complement is approximately 70 per cent above the rated heater voltage; it is only about 10 per cent above the rated voltage for the 18-volt tubes in the five-tube, 100-milliampere complement. These lower surge voltages result in improved receiver reliability and longer tube life by minimizing the possibility of heater burnouts.

**Five-Tube Radio Complement**

The five-tube 120-volt, 100-milliampere complement provides performance equal to that of 117-volt, 150-milliampere complements in a typical commercial radio. This five-tube complement consists of an 18FX6 converter, an 18FW6 if amplifier, an 18FY6 detector-first af amplifier, a 34GD5 beam power tube, and a 36AM3-A rectifier tube.

Except for the adjustment in heater voltage and a slight reduction in heater power, the characteristics and performance of the 18FX6, 18FW6, and 18FY6 are similar to those of their 150-milliampere counterparts. The greatest reduction in heater power was made in the design of the beam power tube and the rectifier tube. Compared with the 35W4, for example, the heater power of the 36AM3-A is reduced by about 30 per cent over the entire heater. The 36AM3-A has a 32-volt main heater section and a 4-volt tap section. This tap section is used as a fuse and a surge-limiting resistor for the B+ supply. Table I lists the B+ voltages for both the 35W4 and the 36AM3-A measured at the input and output of the filter circuit in a typical five-tube radio.

| | 36AM3-A | 35W4 | |
|---|---|---|---|
| AC Line Voltage | 120 | 117 | volts |
| B+ Input to Filter | 126 | 118 | volts |
| B+ Output from Filter | 100 | 95 | volts |

**Note:** Volume control at minimum position; tuning capacitor adjusted for minimum capacitance.

*Table I - Performance comparison of 100-milliampere 36AM3-A and 150-milliampere 35W4 in a typical receiver.*

With slightly more grid-No.1 drive, the 34GD5 provides the same power output as the 50C5 with considerably less heater power at the B+ voltages provided in a typical radio. The power sensitivity, therefore, is slightly lower than that of the 50C5. Table II presents data comparing the performance of the 34GD5 and 50C5 in a commercial radio.

| | 34GD5 | 50C5 | |
|---|---|---|---|
| AC Line Voltage | 120 | 117 | volts |
| Plate Voltage | 120 | 110 | volts |
| Grid-No.2 Voltage | 100 | 92 | volts |
| Cathode-Bias Resistor (Unbypassed) | 120 | 150 | ohms |
| Grid-No.1 Resistor | 0.47 | 0.47 | megohms |
| RMS Grid-No.1 Voltage (1) | 9.7 | 9.0 | volts |
| Load Impedance (2) | 2500 | 2500 | ohms |
| Maximum-Signal Power Output | 1.1 | 1.1 | watts |
| Total Harmonic Distortion | 10 | 10 | per cent |

(1) Voltage applied to grid No.1 through coupling capacitor.
(2) 2500-ohm output transformer terminated with 4-ohm resistive load.

*Table II - Performance comparison of 100-milliampere 34GD5 and 150-milliampere 50C5 in a typical receiver.*

The power drawn from the ac line during typical radio operation is about 20 watts with the 120-volt, 100-milliampere complement as compared with about 26 watts with the 117-volt, 150-milliampere complement at their nominal line voltages. The 120-volt, 100-milliampere complement can be substituted directly for a 117-volt, 150-milliampere complement with no circuit changes in receivers not utilizing panel lamps.

**Four-Tube Economy Radio Complement**

The four-tube complement consists of an 18FX6 converter, a 20EQ7 if amplifier-detector, a 50FK5 power pentode, and a 36AM3-A rectifier tube. The 20EQ7 and 50FK5 were developed specifically for this four-tube complement. The 20EQ7 is a 20-volt version of the 6EQ7 and 12EQ7 tubes used in AM/FM radios and tuners. The pentode section of these tubes is similar to the 18FW6 except for slightly lower transconductance and considerably lower grid-No.1-to-plate capacitance. The low-perveance diode section was especially designed to provide low capacitance between the plate of the diode section and grid No.1 of the pentode section.

Because the suppressor grid (grid No.3) and internal shields of the 20EQ7 are connected to separate base pins, the tube may be used in a variety of circuit configurations. The nine-pin stem and improved shielding provide very low interelectrode capacitances to minimize instability due to feedback between the plates and grid No.1.

Because the four-tube economy complement has only one stage of audio-frequency amplification, greater audio-power sensitivity is required in the power-output stage. Although the 34GD5 beam power tube has higher power-output capabilities, the 50FK5 was designed for use in the four-tube complement to provide this increased audio-power sensitivity. A grid-No.1 voltage of only two volts rms is needed to drive the 50FK5 to full power output (at 10 per-cent distortion) under actual operating conditions. Table III compares the performance of the 50FK5 in the 100-milliampere receiver with that of the 50EH5 in a 150-milliampere four-tube receiver.

| | 50FK5 | 50EH5 | |
|---|---|---|---|
| AC Line Voltage | 120 | 117 | volts |
| Plate Voltage | 120 | 110 | volts |
| Grid-No.2 Voltage | 96 | 92 | volts |
| Cathode-Bias Resistor (Bypassed) | 56 | 56 | ohms |
| Cathode-Bypass Capacitor | 50 | 50 | $\mu$f |
| Grid-No.1 Resistor | 0.47 | 0.47 | megohms |
| RMS Grid-No.1 Voltage (1) | 2.05 | 2.3 | volts |
| Load Impedance (2) | 2500 | 2500 | ohms |
| Maximum-Signal Power Output | 0.85 | 1.0 | watt |
| Total Harmonic Distortion | 10 | 10 | per cent |

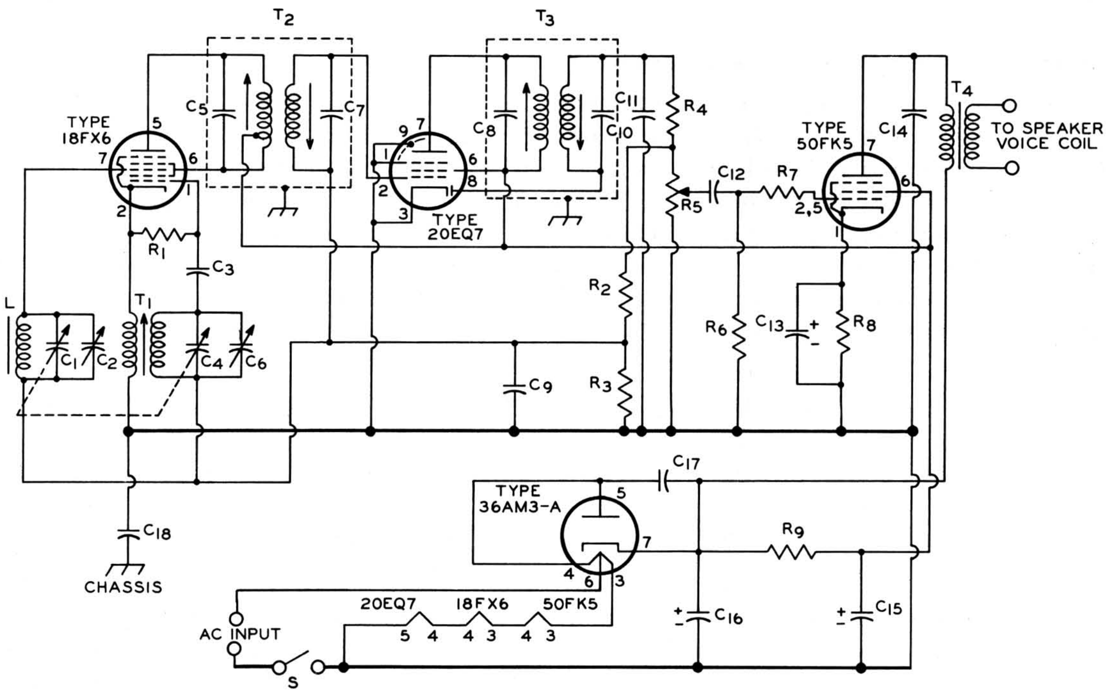
(1) Voltage applied to grid No.1 through coupling capacitor.

(2) 2500-ohm output transformer terminated with 4-ohm resistive load.

*Table III - Performance comparison of 100-milliampere 50FK5 and 150-milliampere 50EH5 in a typical receiver.*

## Experimental Radio Using the Four-Tube Economy Complement

Fig. 1 shows a four-tube superheterodyne receiver which was designed to illustrate one possible arrangement of the economy complement. No special attempt has been made to optimize the values of the parts because the purpose of the circuit is only to act as a guide.




$C_1$, $C_4$: Ganged tuning capacitors; $C_1$, 10–310 $\mu\mu f$; $C_4$, 7–115 $\mu\mu f$
$C_2$: Trimmer capacitor, 2–15 $\mu\mu f$
$C_3$: 56 $\mu\mu f$, ceramic
$C_5$, $C_7$, $C_8$, $C_{10}$: Fixed capacitors; usually part of if transformer assembly
$C_6$: Trimmer capacitor, 2–15 $\mu\mu f$
$C_9$: 0.047 $\mu f$, 400 v., paper
$C_{11}$: 330 $\mu\mu f$, mica
$C_{12}$: 0.01 $\mu f$ 400 v., paper
$C_{13}$: 50 $\mu f$, 15 v., electrolytic
$C_{14}$: 0.015 $\mu f$, 600 v., paper
$C_{15}$: 40 $\mu f$, 150 v., electrolytic
$C_{16}$: 20 $\mu f$, 150 v., electrolytic
$C_{17}$: 0.047 $\mu f$, 400 v., paper
$C_{18}$: 0.1 $\mu f$, 400 v., paper
L: Ferrite rod antenna, 540–1650 Kc
$R_1$: 33,000 ohms, 0.5 watt
$R_2$: 3.3 megohms, 0.5 watt
$R_3$: 1.5 megohms, 0.5 watt
$R_4$: 47,000 ohms, 0.5 watt
$R_5$: Volume control, potentiometer, 1 megohm
$R_6$: 470,000 ohms, 0.5 watt
$R_7$: 10,000 ohms, 0.5 watt
$R_8$: 56 ohms, 0.5 watt
$R_9$: 1200 ohms, 1 watt
S: Switch; single pole, single throw
$T_1$: Oscillator coil for use with 7–115-$\mu\mu f$ tuning capacitor and 455-Kc if transformer
$T_2$: Input if transformer, 455 Kc, tapped (see text)
$T_3$: Output if transformer, 455 Kc
$T_4$: Output transformer for matching impedance of voice coil to 3000-ohm tube load (Triad S-16X or equivalent)

*Fig. 1 - Experimental four-tube economy receiver utilizing 120-volt, 100-milliampere complement.*

As shown in Fig.1, the converter stage of the four-tube receiver is conventional except for the addition of a tap to the primary of the first if transformer. This tap furnishes increased gain from the converter stage by (1) providing neutralization which, in turn, reduces the loading on the antenna, and (2) introducing a small load impedance in the screen-grid circuit. The voltage developed across this impedance adds in phase with that developed in the plate circuit to supply some additional gain. When an antenna having relatively high Q is used, the over-all increase in gain resulting from use of the tap approaches 2:1.

The if and detector stages are also essentially conventional. The combination of high gain from the converter and if stages and reduced audio gain causes the avc voltage to be so large under strong-signal conditions as to limit the amount of audio voltage fed to the power-output stage. As a result, it is necessary to reduce the avc voltage by means of a voltage divider in the avc line. The value of the resistor used in the voltage-divider network should be chosen to provide a balance between strong-signal overloading and sensitivity for rated output.

A 10,000-ohm resistor is used in the grid-No.1 circuit of the 50FK5 to reduce the likelihood of parasitic oscillations. Otherwise, the power-output stage is essentially conventional.

The rectifier circuit is also conventional. Because measurements indicated reduced hum in the single-audio-tube circuit, the values of the filter capacitors were reduced from the usual 50- and 30-microfarad capacitors used in the five-tube receiver to 40 and 20 microfarads.

The experimental four-tube receiver has a sensitivity of approximately 500 microvolts per meter as compared with 150 microvolts per meter for the 100-milliampere five-tube receiver. Otherwise, performance of the two receivers is essentially the same. The action of the volume control is, however, slightly different. The increase in power output with rotation of the volume control is less than that of the five-tube receiver. The power drawn from the ac line is approximately the same. Some improvement in the over-all performance of the four-tube receiver can be realized by the use of plate or screen-grid reflexing of the audio signal through the if-amplifier stage.

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