SYLVANIA engineering information service

Vol. 1
No. 11
AUGUST
1954

Tube Requirements for Series String Operation in TV Receivers

INTRODUCTION

The use of series heater strings in tv receivers has been considered for sometime throughout the television industry. The potential advantages of series string operation are widely recognized, and include a cost reduction by elimination of a filament transformer, and possible direct rectification of line voltage without recourse to a step-up transformer. The savings in space and weight will allow more flexible chassis design and mounting which results in a smaller and more portable set.

Heretofore, because of the different heater current ratings ranging from 150 to 1200 ma, it was necessary to use series parallel strings, or shunted tubes to maintain the proper static heater voltage distribution in the series string. Then, because of the non-uniformity of thermal characteristics, excessive surge voltages could appear across the heaters of the lower heater current tubes. When a negative temperature coefficient device had to be used to eliminate these surges, the receiver would take almost two minutes to stabilize.

These disadvantages have recently been alleviated by the development of a new line of 600 ma heater current tubes which perform all the necessary functions in modern television receivers. A list of the currently available types is presented in Table I. Heater current tolerances have been narrowed to ±4% on all types listed. The tube types in the table, whose prototypes previously had heater currents less than 600 ma have increased wire size and decreased heater voltage. These features tend to make them more rugged and will improve their reaction to voltage or power surges. Controls have also been instituted on the thermal heater characteristics of all of the television series string tube types to minimize such surges.

TABLE I

SERIES HEATER STRING TUBE TYPES

2AF4	3BZ6	5J6	12AX4GTA
2T4	3CB6	5T8	12B4A
3AL5	4BQ7A	5U8	12BH7A
3AU6	4BZ7	5V6GT	12BK5
3AV6	5AM8	5X8	12BQ6GA
3BC5	5AN8	6AW8	12BQ6GTA
3BE6	5AQ5	6AX7	12BY7A
3BN6	5AV8	6S4A	12CU6
3BY6	5BK7A	6SN7GTB	12L6GT
			12W6GT
			25CD6GA

HEATER WARM-UP TEST TO CONTROL THERMAL CHARACTERISTICS

Since heater voltage surges in series string operation are principally due to differences in thermal characteristics of the heater structures of the tubes, some method had to be defined to control this characteristic. At present, the generally accepted method of controlling these thermal characteristics in production is the "heater warm-up time" test. In this test, the measured time is that required for a heater, originally at room temperature, to reach 80% of its rated voltage after four times the rated voltage is applied to the heater in series with a fixed resistor. This fixed resistor is specified as three times the rated hot resistance of the tube's heater. The heater warm-up time for all tube types in this new 600 ma line has a design center rating at 10 seconds.

The importance of such a test for evaluating the thermal characteristics of the heaters is readily apparent when considering a tube with fast warm-up time in a series string of tubes which exhibit slower warm-up properties. The fast heating tube will receive an excessively high voltage surge across its heater until the remaining heaters assume their share of the applied voltage. Heater warm-up time measurements by this test method will indicate the probable occurrence of surge voltages on heaters in series strings, although not the magnitude nor time of this occurrence.

ASPECTS OF SERIES STRING OPERATION

The new Sylvania 600 ma heater current tube types with the previously mentioned controls will affect the following aspects of tv series string operation: Steady-state voltage distribution in series heater strings, voltage distribution during warm-up, surge currents, and receiver operation with series strings.

STEADY-STATE VOLTAGE DISTRIBUTION IN SERIES HEATER STRINGS

To assure proper functioning in series string operation, careful attention must be paid to the steady-state distribution of heater voltages across the tubes in the string. While heater current is not too critical under the constant voltage conditions with transformer heater supplies, it is very important under the constant current conditions of the series string because the division of heater voltage is determined by the hot resistance of the individual tubes. To minimize these effects in series string operation, heater current limits on the new 600 ma line of tubes have been narrowed to 575-625 ma with a 600 ma rating.

The representative heater voltage (Ef) — heater current (If) characteristic of typical new Sylvania 600 ma tube types is shown in Fig. 1. The total area represents the maximum voltage and current excursions due to high and low heater current tubes under conditions approximating rated (117 V.), high (130 V.), and low (105 V.) line conditions. These maximum excursions may occur only when the string current is near one limit (575 or 625 ma) and the heater current of the tube in question, as measured at its rated voltage is at the other limit (625 or 575 ma).

The probable area within which these 600 ma tubes will operate will be smaller in comparison to the total area and will be determined by the heater current spread of the tubes and the probable variation of the current in series strings composed of these tubes. Statistical analysis indicates that 95% of the 600 ma tube production should fall within ±16 ma of the design center rating for heater current. As a result, the string current for 99.7% of the probable combinations of tubes, for an arbitrary 15 tube series string, will fall within ±6 ma of the same design center. Although variations in 15 tube complements will theoretically affect the probable range of string current, practically, this effect is negligible. For a larger number of tubes in a series string, this ±6 ma figure will decrease proportionally, while for a smaller number, the converse is true. These conditions of probable operation at rated line conditions are graphically represented by area A on the Ef-If characteristic of Figure 1 for a 15 tube string. Areas B and C, which represent the probable range of tube operation for high and low line conditions, were determined in a similar manner. While these areas of probable operation, A, B, or C, individually represent only 15% of the area of possible operation for rated, high, and low line conditions, these areas of possible operation overlap on a concurrent presentation. Areas B and C of probable operation at high and low line will slide through the areas X into area A as the line voltage approaches normal. Therefore, the range of probable operation for 95% of the 600 ma tube production used in 15 tube strings will be only 43% of the maximum possible operating range considering low line to high line operation, or 15% of the possible range considering any single line condition.

To determine the probable operating point of a tube on this Ef-If presentation, the string current at rated line and the heater current at rated heater voltage of the tube in question must be known. This heater current value will determine which of the family of Ef-If curves, all parallel to the bogey characteristic, should be used for this tube. The string current may be determined for a change in line voltage from the following formula:

$$I_a = I_r - 0.315 + \left(\frac{0.315}{E_r}\right) E_a$$

Where I_a = string current
I_r = string current at rated line
E_r = rated line voltage (117 V.)
E_a = actual applied line voltage

The intersection of the string current line and the individual tube current characteristic will be the approximate operating point for this tube. The above formula will hold if the series resistor in the series string is less than 20% of the total string resistance at rated voltage and current. As the value of this series resistor is increased, the voltage and current excursions of the tubes will increase slightly from that shown for corresponding changes in applied voltages and slight error will also be introduced in the string current calculations.

While tighter heater current tolerances (600 ± 25 ma) have reduced the probable string current variation, the foregoing discussion points out the possible variations in heater excitation that may still exist on individual tubes in series string operation.

TABLE II
TYPICAL SERIES HEATER STRING

**RMS Voltage	Complement	Probable* Peak EHK	Function
117 V.A.C.	45.5 ohms		
89.7	12AX4GTA	3000 V.	Damper
77.1	12BQ6GTA	111 V.	Horiz. Output
64.5	3BC5	91 V.	R.F. Amplifier
61.35	5J6	87 V.	Osc.-Mixer
56.65	3CB6	80 V.	1st Video If
53.5	3CB6	76 V.	2nd Video If
50.35	5AN8	71 V.	3rd Video If Sync. Sep.
45.65	6AW8	67 V.	Video Amp. AGC Amp.
39.35	5AN8	56 V.	1st Sound If Sync. Amp.
34.65	12BH7A	170 V.	Vert. Osc. and Output
28.35	12L6GT	190 V.	Audio Output
15.75	3BN6	23 V.	Sound Limiter Detector, Amp.
12.6	6SN7GTB	23 V.	Horiz., Osc. and AFC
6.3	Pix Tube	Up to 160 V.	Picture Tube
	1X2B		† Hi Voltage Rectifier

* *Heater Negative*
** *Theoretical Distribution*
† *Filament Operated from Horiz. Deflection Transf.*

ENGINEERING INFORMATION SERVICE
a technical publication of
SYLVANIA ELECTRIC PRODUCTS INC.
RADIO TUBE DIVISION, EMPORIUM, PA.

VOL. 1 AUGUST, 1954 No. 11

Since it is impractical for the tube manufacturer to reduce heater current tolerances less than the newly established ±4% limits, a knowledge of possible and probable heater power variations is especially necessary inasmuch as it may affect the design of critical circuits where high performance and tube life are important. Design of circuits where noise figure, scan, sensitivity, and high voltage are critical, must therefore be more conservative for series string operation than for operation from a filament transformer.

VOLTAGE DISTRIBUTION DURING WARM-UP

As stated previously, voltage surges occur across the heaters of tubes in series string operation because of differences in thermal characteristics. These surges will appear across the heaters which tend to heat rapidly, until the slower heating tubes warm sufficiently to take their share of the string voltage. While life test information to date indicates that surge voltages up to 50% above rated heater voltage can easily be tolerated, any reduction below this value will further improve the overall reliability of the string. Actually, if all tubes in the string had the same thermal characteristics, no voltage surges would occur.

Surge voltage measurements vs. time are shown in Figs. 2 through 5 for near bogey heater current tubes in the typical series string of Table II. This string is composed of the new 600 ma tubes with a range of heater warm-up time from 7.5 to 12.6 seconds, and a 45 ohm series resistor. The recorded measurements show that the maximum heater voltage surge was only 25% above rated voltage, on the Type 5AN8, which happened to have the fastest warm-up time. On the remainder of the tubes, the maximum surge was less than 10% above rated heater voltage. Reference to Figs. 2 through 5 shows how the occurrence of surge voltages may be predicted by heater warm-up time measurements which are included on the individual curves. A tube which happens to be near the minimum warm-up time limits will take the

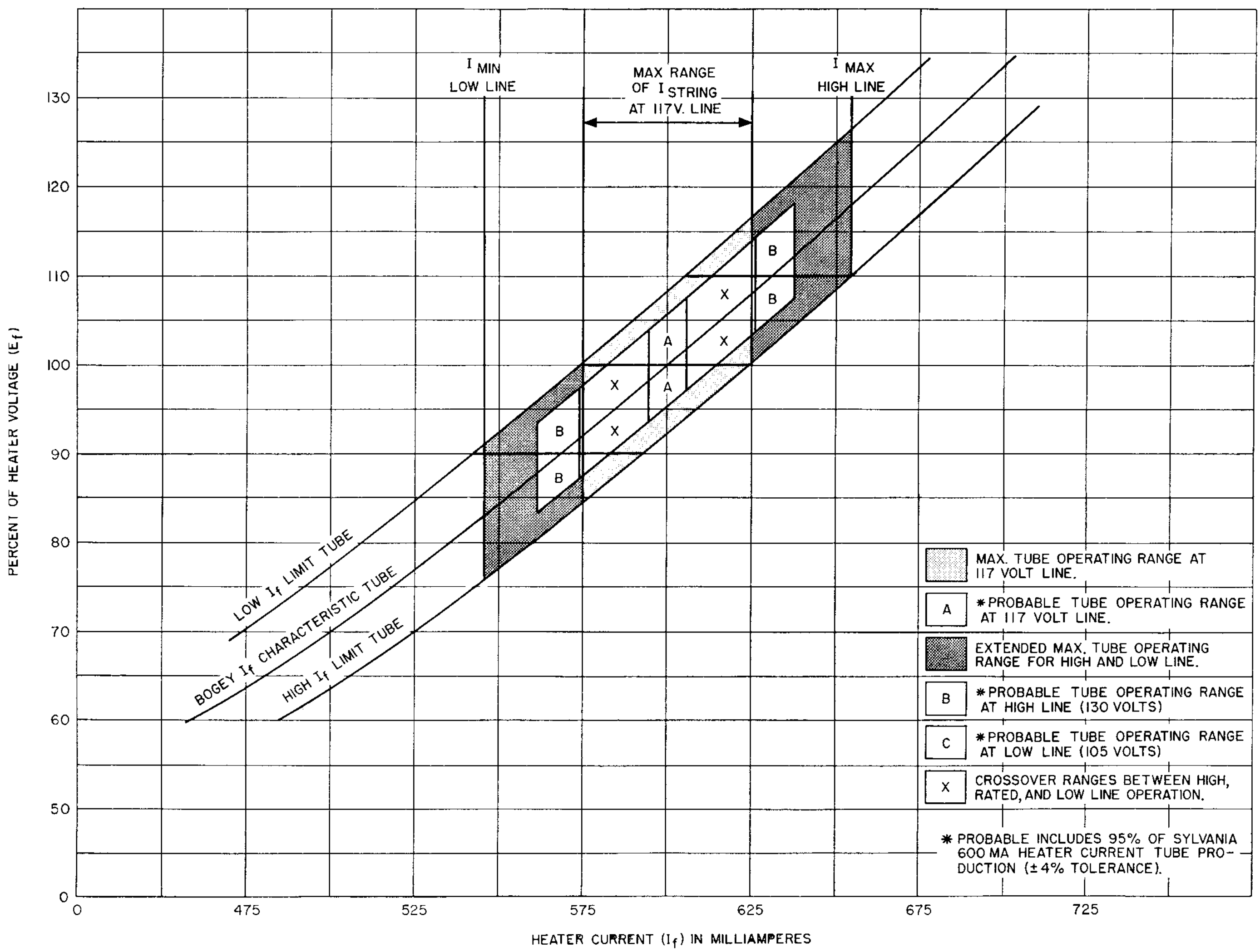
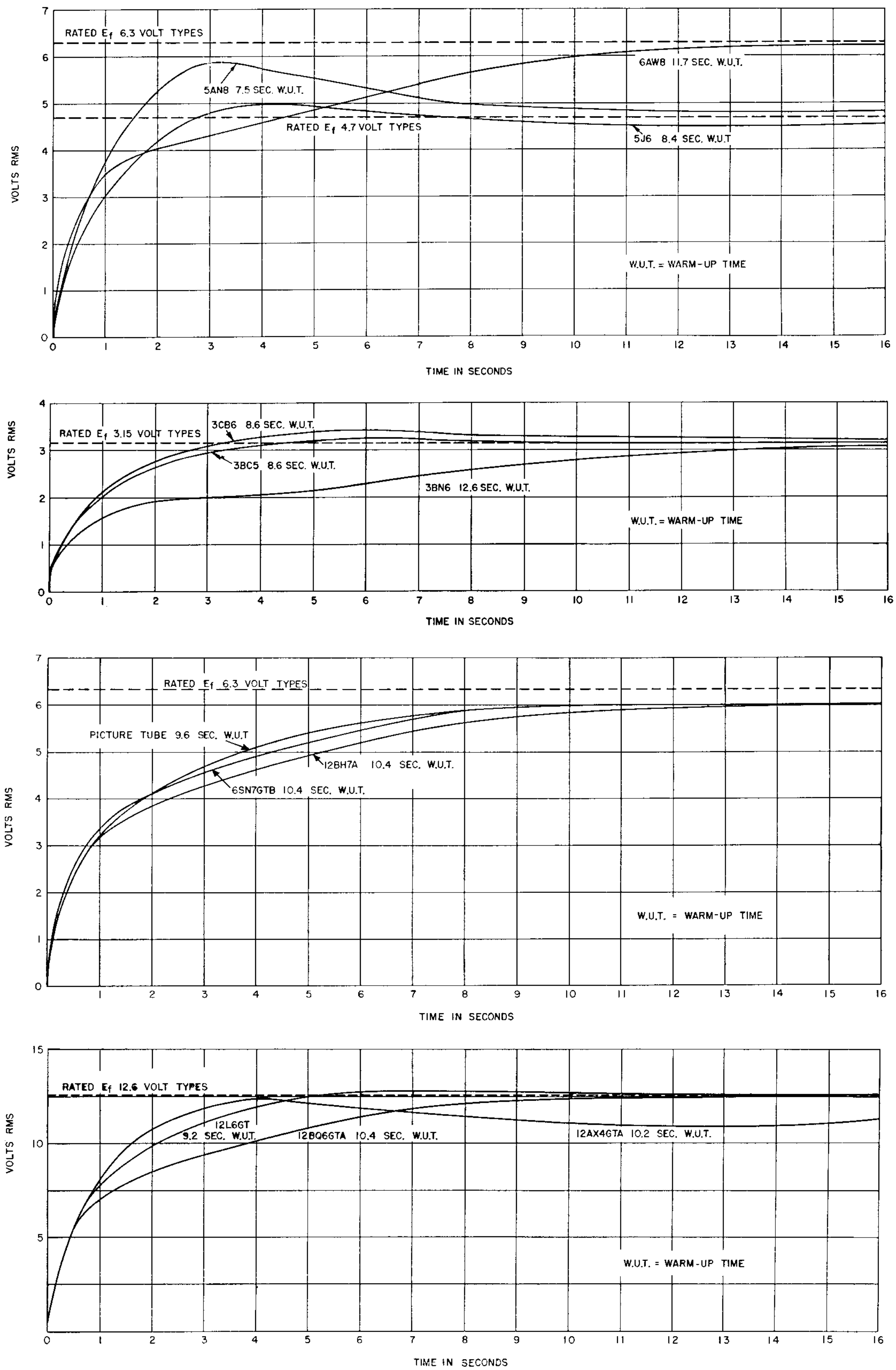


FIG. 1 — E_f-I_f CHARACTERISTIC AND OPERATING RANGE FOR SERIES STRING TYPES

FIG. 2-5 — SURGE VOLTAGE MEASUREMENTS BASED ON TYPICAL STRING SHOWN IN TABLE II



highest surge at the earliest time. For example, the particular 5AN8 shown in Fig. 2, having a 7.5 second warm-up, had a 25% over-rated heater voltage surge at approximately 3 seconds. For a tube with somewhat greater heater warm-up time, the voltage surges are smaller in magnitude and delayed in time. For example, the particular Types 5J6, 3BC5 and 3CB6, shown in Figs. 2 & 3, having approximately a 9 second warm-up time, had slight voltage surges appearing between 4 and 7 seconds. A tube with average heater warm-up time, around 10 seconds, shows no surge voltage and its warm-up curves approximate a critically damped wave, stabilizing near 10 seconds. Examples of this are the particular 12L6GT, 6SN7GTB and picture tube, shown in Figs. 4 and 5, with warm-up times between 9 and 10.5 seconds. A tube with heater warm-up time greater than 11 seconds is slower to assume the proper heater voltage. For example, the particular 6AW8 and 3BN6 shown in Figs. 2 and 3 required 14 seconds or more for the heater voltage to stabilize. The Type 12AX4GTA, because of its heater-cathode assembly, is the only exception to the foregoing trend. This type will normally be slower for operational heating time even though its measured heater warm-up time is 10 seconds. It is constructed with an insulating sleeve between the heater and cathode which must be brought up to temperature to conduct heat to the cathode. This is graphically illustrated in Fig. 5 when the heater assumes near rated heater voltage in 4 seconds. This voltage then slumps off slightly due to the heating of the insulating sleeve and thereafter slowly rises to its final heater voltage. This insulating sleeve effectively delays the cathode current and prevents the high voltage from being applied to the picture tube before its cathode is sufficiently heated.

Since tubes with heater current near bogey were used in this string, the surge voltages may be attributed almost entirely to differences in thermal or heater warm-up characteristics. The measurements indicate the extent to which surge voltages may be controlled in a series string with 45 ohms series resistance.

SURGE CURRENTS

A surge of heater current occurs in a tube at the instant voltage is applied regardless of the type of heater voltage supply. This surge is the result of voltage being applied to heaters whose "cold" resistances are approximately 15% of their "hot" values at rated voltage. In a c operation, the maximum possible surge current occurs when the supply voltage is applied at the time of its most positive or negative peak. For the typical series string shown in Table II, the maximum peak surge current theoretically possible was only 2.5 amperes. The measured value was actually lower due to the limiting effects of source impedance and contact resistances. This 2.5 amperes is almost a 2 to 1 reduction from the 4.5 ampere peak current surge theoretically possible on a 600 ma heater across a 6.3 volt filament winding of a similar transformer powered tv set. If no series resistor were included in the string, the peak surge current could exceed that possible in transformer operation by approximately 30%. Although these surge currents decay rapidly during the first one-quarter second, they may be reduced, in series string operation, to the point where practically no instantaneous power surge occurs, by increasing the value of the series resistance.

RECEIVER OPERATION WITH SERIES HEATER STRINGS

The question of how soon the receiver will operate now arises. In experimental receivers using the typical series string discussed herein, observations have shown that over 90% of rated heater voltage will appear across each tube within 10 seconds and a normal raster will appear between 45 and 55 seconds after power is applied. Use of thermistors or negative temperature coefficient resistors in place of the 45 ohm series resistor will delay appearance of the raster to 90 - 120 seconds. Receivers using transformer heater supplies will produce a raster in 20 to 30 seconds. Although still not as fast as in transformer operation, series strings composed of the new line of tubes with 600 ma heaters, and fixed series resistors, will show a great improvement in time required for stable receiver operation over strings which utilize thermistors to eliminate voltage surges.

Peak heater-cathode voltages on tubes operated in series (cascode operation), or tubes operated as voltage dropping elements (audio output) may reach values in excess of 300 volts at rated line conditions depending on their location in the series string and their d c cathode potentials. Good practice is to place these tubes near the low voltage end of the string to reduce the peak voltage added to the normal d c component with the heaters operating off ground. Placement of these tubes as in Table II shows how all tubes may be kept within a 200 V. peak heater-cathode voltage rating. Most tubes of this new 600 ma line carry this rating.

CONCLUSIONS

Conclusions that may be drawn from the foregoing discussion include:

(1) Series string operation of tubes in tv receivers can have distinct advantages appearing in the form of cost reductions and dimensionally smaller sets.

(2) Series strings composed of the new 600 ma line of tubes with controlled thermal characteristics will have greater life expectancy from a heater burnout viewpoint than older types used in shunt or series parallel, due to the minimization of surge conditions.

(3) A receiver using these series strings and a series resistor will require less than half the time to operate normally than one which must use a thermistor.

(4) Closer heater current tolerances have minimized possible heater power variations in series strings, but conservative design of critical circuits is still necessary to counteract the effects of high and low line operation.

(5) A series resistor in the string will reduce or practically eliminate peak power surges across the tubes at the moment voltage is applied.

SYLVANIA engineering information service

Vol. 1
No. 12
DECEMBER
1954

Television Picture Tubes for Series Heater Operation

INTRODUCTION

The development of a practical series heater string television receiver has resulted in the introduction of a new line of 600 ma television receiving tubes and modification of picture tube manufacturing and testing specifications. Application data and a listing of the new receiving tubes appeared in the August, 1954 issue[1] of ENGINEERING INFORMATION SERVICE. The present article provides additional information on picture tubes for series heater operation.

SERIES STRING TYPES

Picture tubes for series heater strings have not been introduced as a new line. Television picture tubes intended for transformer operation already incorporate a design center heater current rating of 600 ma and have relatively high heater-cathode voltage ratings. Narrowing of heater current limits, in agreement with the newly developed receiving tubes (600 ±25 ma) and control of thermal characteristics in production, now provide the necessary protection against failure due to surge voltages or improper steady state voltage distribution. These changes have been made possible by a redesigned heater coil, closer wire weight tolerances and better control of the heater insulating coating.

PICTURE TUBE CONSIDERATIONS

In the case of picture tubes, a number of problems arise which are not present to so great an extent in many other tubes. An important difference is the cathode area available for emission; emission in a picture tube is from an area so small (approximately 35/1000 inch diameter) that it approximates a point source of electrons. This is required since electron lenses, analogous to optical lenses, are used to focus the image of this spot upon the screen. As a result of this requirement of a small area cathode with high emission density, the shape of the picture tube cathode is such that emission is from the small cathode end surface rather than from the cylindrical walls. This physical construction necessitates the use of a double helix reverse coiled type heater rather than a folded type, and also greatly restricts the size and shape of the space available for the heater. The cathode and heater of a picture tube are compared with a receiving tube cathode and folded heater in Figure 1.

1. *"Tube Requirements for Series String Operation in TV Receivers", ENGINEERING INFORMATION SERVICE, Vol. 1, No. 11, August 1954. Additional copies available from Sylvania Electric Products Inc., Central Advertising Distribution Department, 1100 Main Street, Buffalo 2, New York.*

Another important factor for consideration in the warm-up time of picture tubes is a result of the smaller emitting area of the cathode and the higher anode voltages as compared with most other tubes. Sufficiently rapid cathode heating or lag in the circuits that develop the anode voltage is desirable to prevent having the high voltage applied to the picture tube while emission is in the temperature limited state. Emission during such time could well create "hot

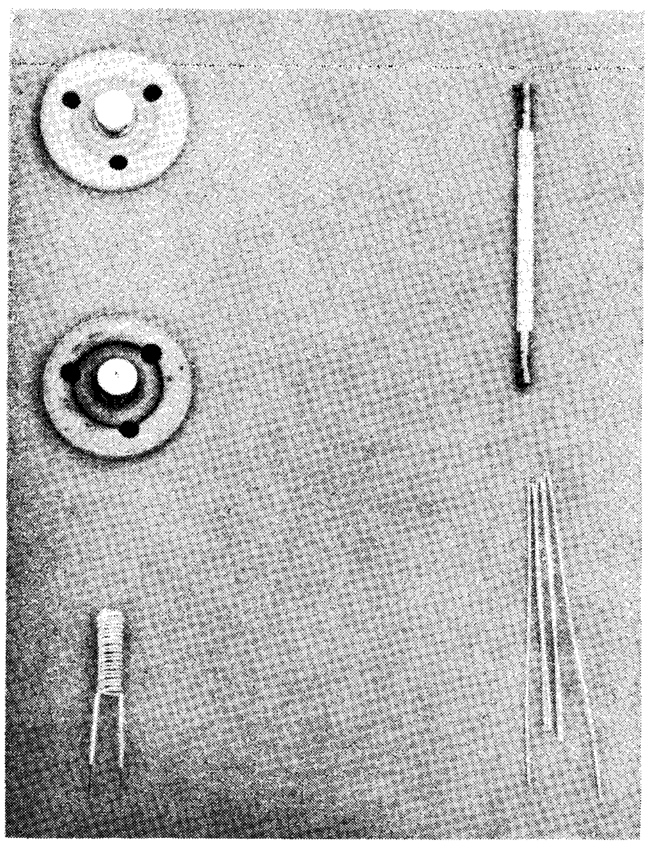


Figure 1 — Comparison of picture tube cathode and heater (left) with receiving tube cathode and heater (right). Note damaged spot in picture tube cathode shown at middle left.

spots", i.e., points on the cathode where the emission density would be excessive. Since emission at that time is temperature limited, the space charge of electrons near the cathode is absent, and some flux lines from the anode terminate directly upon the cathode surface. This tends to increase the possibility of ion bombardment of the cathode which may kill the emission in the "hot spot" by removing particles of the cathode coating and perhaps produce gas in the tube.

When one recalls that the used portion of the picture tube cathode area is about 35/1000 inch diameter, it becomes evident that a "hot spot", which would be only a minute portion of a receiving tube's cathode, would impair the picture tube cathode.

Preventing the application of the picture tube anode voltage until the picture tube cathode is no longer temperature limited is accomplished by an inherent characteristic of the newly designed 12AX4-GTA damping diode. Although the heater of the 12AX4GTA has a heater warm-up time approximating 10 seconds, an insulating sleeve between the heater and cathode delays cathode emission for a somewhat longer period, thus preventing application of the picture tube anode voltage until its cathode is sufficiently heated.

CONCLUSION

Tighter heater current limits (600 ±25 ma) and control of heater thermal characteristics in production, similar to the newly introduced series string television receiving tubes, minimize the possibility of picture tube failure due to improper steady state voltage distribution and surge voltages in properly designed series heater circuits. The life expectancy and performance of the picture tube in such circuits should be comparable to that achieved with transformer operation.

For complete heater circuit design data, the reader is referred to the reference article mentioned in the introductory paragraph.

ENGINEERING INFORMATION SERVICE

a technical publication of

SYLVANIA ELECTRIC PRODUTS INC.
RADIO TUBE DIVISION, EMPORIUM, PA.

VOL. 1 DECEMBER, 1954 No. 12

JUNE—JULY 1956
Vol. 8, No. 3

GE Electronic TUBES
Techni-talk
on AM, FM, TV Servicing

NEW
300 AND 450 MA SERIES-STRING TUBES

Many of the latest model TV receivers will use series-string tubes. Some of these receivers will use 300-ma type tubes, some will use 450-ma type tubes and others will use 600-ma type tubes. Regardless of the current required by the tube heaters they will all have controlled warm-up time if used in a series-string circuit.

Receivers with their heaters connected in series have been manufactured for quite a few years and most service technicians are familiar with this type circuit. Prior to 1954 some tubes designed for parallel connected heaters were used in series-string circuits. When used in series-string circuits, some of these tubes did not perform as well as when used in parallel heater circuits. In 1954 it was decided that in view of the trend to lower price receivers a line of tubes should be developed specifically for series-string operation.

It was found that tubes had to be improved in two ways for series-string operation. First, the heater-cathode voltage rating had to be increased because the full a-c line voltage in addition to any applied d-c voltage might be present between these two tube elements. Second, each tube in a series-string circuit had to warm-up at practically the same time. This was necessary in order to prevent any high voltage surges across any particular tube heater.

Both of these improvements were made in a line of tubes first introduced by General Electric and known as the "600 Series" receiving tubes. The heaters used in these tubes as well as all General Electric picture tubes are so designed that all tubes warm-up within a certain specified time interval. High voltage surges across any tube heater are eliminated and voltage limiting devices are not required.

The development of the "600 Series" receiving tube made possible lower cost TV receivers and initiated the "swing" to portable receivers by a number of TV manufacturers. The service technician has benefited from this in two ways. First, due to lower priced receivers, more people have purchased a second set. Since two receivers require more service than one, more potential service business is now and will continue to be available. Second, portable TV receivers can be brought into the service shop. This type of business should be encouraged since many more receivers can be serviced in a day if travel time can be eliminated. There will also be more profit in this type of service because all of the expenses necessary for home servicing will be reduced. These expenses include gas, oil, depreciation on vehicle, insurance, repairs, etc. The service technician should, therefore, welcome these latest advances made by the tube industry.

The "600 Series" tubes have been used in many series-string type receivers with excellent results. It has been found, however, that since the voltage across all of the tube heaters used in series-string receivers seldom equaled the line voltage, some additional component was required to provide proper heater voltages. One method was a tapped transformer such as used on the General Electric "N" line of receivers shown in Fig. 1. This tap provides about 90 volts at 600 ma.

Another method commonly used is a wire wound resistor such as used in the General Electric "M" chassis shown in Fig. 2. Notice that R-401 is a 40-watt

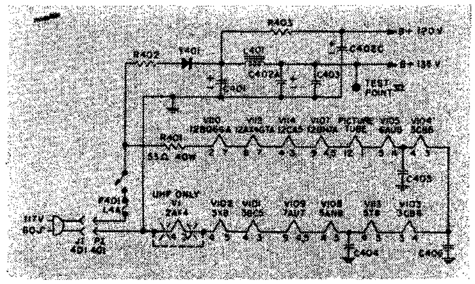


Fig. 2. Series-heater circuit with resistor used in General Electric "M" line of receivers.

resistor which dissipates a considerable amount of heat. This heat presents a problem to both the manufacturer and the purchaser. The manufacturer must make provision for proper ventilation and the purchaser must pay for the unwanted heat. Since the cathode in each tube requires a specific amount of heat (supplied by the heater) for proper operation, the only significant heat reduction would be to either eliminate the voltage dropping resistor or reduce the current flow through this resistor. This is precisely what was accomplished by the development of the "300 Series" and "450 Series" tubes with controlled warm-up time.

An up-to-date list of all tubes with controlled warm-up time and their prototypes is shown in the chart on pages 2 and 5. It will be noted that some types such as the 6AU6-A and 6CB6A are listed as "300 Series" tubes. Since their prototypes, the 6AU6 and 6CB6, are also 300-ma type, the only difference between the "300 Series" and their prototypes is in the controlled warm-up time characteristic of the heater.

It will also be noticed that there are several versions of a single tube type such as the 7AU7, 9AU7 and the 12AU7, with the 7AU7 listed in both the "300 Series" and "600 Series" columns. The only difference between the 7AU7, 9AU7 and the 12AU7 is the heater voltage and current. Since the 7AU7 has a center-tapped controlled warm-up time heater, it can be used as either a "300 Series" or a "600 Series," depending on the way the heater is connected.

Since the only difference between the new tubes and their prototypes is in the heater, many of these tubes can be tested if the proper heater voltage tap is available. All *other* tube tester settings for the prototype can then be used.

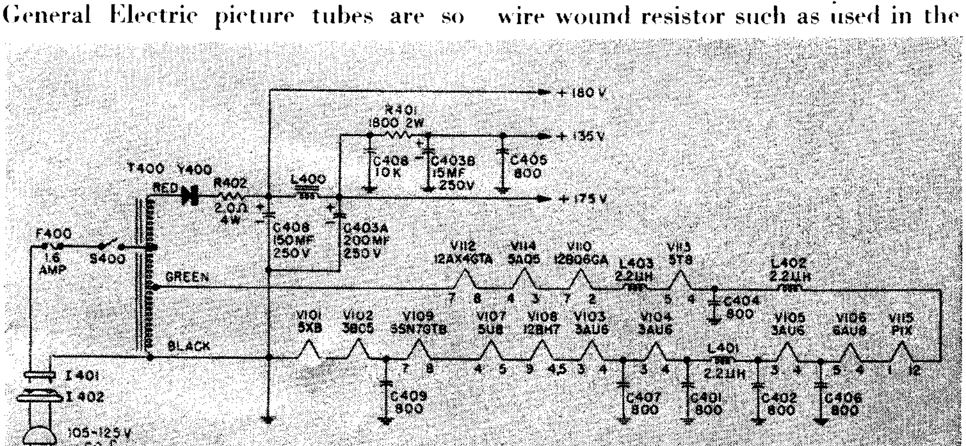


Fig. 1. Transformer-type supply for series-heater circuit used in General Electric "N" line of receivers.