Design-Maximum System for Rating Electron Tubes

Ratings are established on electron tube types to guide and assist equipment designers in utilizing to best advantage the performance and service capabilities of each tube type. Rating values are provided for those tube characteristics for which careful study and experience indicate limiting values are required to insure satisfactory performance.

In order that the numerical values of a rating system have significance, the system used must be accurately defined and properly applied.

Electron Tube Rating Systems

Three Rating Systems are in use by the Electron Tube Industry. The oldest is known as the Absolute-Maximum System, the next as the Design-Center System, and the latest and newest is the Design-Maximum System. Definitions of these systems formulated by the Joint Electron Tube Engineering Council (JETEC) and standardized by NEMA and EIA are given in the JETEC publication J5-C3 dated May 1, 1957 appended to this Note.

The latest system and the one with which this Application Note is particularly concerned is the Design-Maximum System. This system and its application are described in detail in J5-C3. It should be carefully studied by designers of equipment using entertainment-type receiving tubes.

The numerical values of the various ratings shown under the three systems are not directly comparable because of certain allowances (factors of safety) made for equipment, component, and adjustment tolerances, supply-voltage variations, environmental conditions, and tube variations as prescribed by the definition of the system used.

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RADIO CORPORATION OF AMERICA, HARRISON, NEW JERSEY

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The significant differences between the three Rating Systems can be summarized as follows:

Absolute-Maximum System:

$$\text{Ratings} = \begin{bmatrix} \text{Maximum capabilities} \\ \text{of any tube of} \\ \text{the type rated} \end{bmatrix}$$

Design-Center System:

$$\text{Ratings} = \begin{bmatrix} \text{Maximum capabilities} \\ \text{of any tube of} \\ \text{the type rated} \end{bmatrix} - \begin{bmatrix} \text{Allowance} \\ \text{for tube} \\ \text{variations} \end{bmatrix} - \begin{bmatrix} \text{Allowance for} \\ \text{component and} \\ \text{supply variations} \end{bmatrix}$$

Design-Maximum System:

$$\text{Ratings} = \begin{bmatrix} \text{Maximum capabilities} \\ \text{of any tube of} \\ \text{the type rated} \end{bmatrix} - \begin{bmatrix} \text{Allowance} \\ \text{for tube} \\ \text{variations} \end{bmatrix}$$

These expressions show clearly why a tube of any given type might be rated with entirely different numerical values, depending on the system used, although in effect it is rated at the same capability level in each system. When the equipment designer uses tube-rating values, he must be careful to note the system used and must take into consideration the appropriate allowances.

The definitions specify whether bogey or limit tubes of a type should be used when the equipment designer wants to determine whether his design uses that tube type within its ratings. For the Design-Center and Design-Maximum Systems, normal, average, or bogey tubes should be used; for the Absolute-Maximum System, limit tubes are necessary.

Under the Design-Maximum System, a bogey tube should be put into the socket under test while measurements of voltages, currents, temperatures, or other characteristics as designated by the data sheet are made under the worst probable or limit values of line voltage, environmental conditions, equipment components, or equipment adjustment.

Note that this procedure differs from that used in checking under the Design-Center System where the same bogey tube would be used but the measurements would be made under the normal, or bogey, conditions for line voltage, environment, equipment adjustment, and component tolerances.

If the check were to be made under the Absolute-Maximum System, it would be necessary to make the measurements not only at the worst probable conditions for the equipment variables, but also with a limit tube of the type under consideration instead of the bogey one which is used in the other two systems.

Benefits of Design-Maximum System

The use of the Design-Maximum System of Ratings for entertainment-type receiving tubes is expected to benefit both equipment manufacturers and tube manufacturers. One of the benefits of this system is that it provides for the safety factors to be determined by the equipment or tube design groups best able to evaluate them. The equipment designer is better able to allow for the variations in use and design of his equipment; the tube manufacturer is better able to judge the allowance in ratings needed due to variations of his product.

Because better judgment can be used in determining these allowances, improved tube performance can be expected through:

(1) Better life. Tube manufacturers can cover ratings more realistically on their life tests.

(2) Fuller benefit of tube ratings. Equipment designed with close tolerances can safely use tubes at the published numerical ratings.

(3) More reliable tube usage. The appropriate allowance for equipment is determined by the equipment designer who is better able to make this evaluation than the tube manufacturer.

Because of the advantages of the Design-Maximum System, RCA plans to use this system on all new entertainment-type receiving tubes. Ratings for the more popular entertainment types already published in the Design-Center System will be reissued in the Design-Maximum System.

RCA

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The Design-Maximum Rating System for Electron Tubes

Prepared by JTC-5 Committee on
Low Power Vacuum Tubes

Distributed by

ELECTRON TUBE DIVISION
RADIO CORPORATION OF AMERICA
Harrison New Jersey

THE DESIGN-MAXIMUM RATING SYSTEM FOR ELECTRON TUBES*

The purpose of this bulletin is to present the basic concepts of the new Design-Maximum Rating System. After a brief review of the background which led to the development of the new system, the principles of the Design-Maximum System as applied to receiving tubes and its application to circuit design will be presented. Finally, specific examples of selected tube application will be included to indicate the proper use of the system.

APPENDIX #1 **

*Prepared by JTC-5 Committee on Low Power Vacuum Tubes.

**This is the initial JETEC Publication illustrating the application of the "Electrical Rating Systems for Electron Devices", which are Design-Maximum, Design-Center, and Absolute-Maximum Systems.

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INTRODUCTION

NEED FOR A RATING SYSTEM

The conditions under which an electron tube may be operated are limited by fundamental capabilities of the tube itself. Physical limitations exist, for example, in the permissible temperatures at which the various electrodes may be operated, in the amount of current which can be emitted by the cathode, and in the voltage gradients which may be permitted between the various tube elements.

Maximum tube ratings have been established to define these various physical limitations of the tube in terms of readily measurable quantities. The numerical quantities presented as maximum ratings indicate the limiting operating values required to assure satisfactory tube life and performance.

Before the value of any rating can become meaningful, the rating system on which the rating is based must be specified. The system must define the interpretation required of the numerical values and indicate the procedure necessary to determine whether or not a tube is operating within its rating.

Until the present time, two rating systems have been commonly used in conjunction with receiving tubes, the Design-Center System and the Absolute-Maximum System.
The problems created by their deficiencies have greatly intensified in recent years primarily as a result of the greatly increased scope of receiving tube applications.
To overcome the deficiencies encountered with the two rating systems in current use, a new system for rating tubes, designated the "Design-Maximum System" has been developed.

DEFINITIONS OF EXISTING SYSTEMS

The following definitions have been standardized by the tube industry to describe the two systems which have been in common use:

DESIGN-CENTER RATING SYSTEM

Design-Center ratings are limiting values of operating and environmental conditions applicable to a bogey electron device of a specified type as defined by its published data, and should not be exceeded under normal conditions.

The device manufacturer chooses those values to provide acceptable serviceability of the device in average applications, taking responsibility for normal changes in operating conditions due to rated supply voltage variation,* equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in device characteristics.

The equipment manufacturer should design so that initially no design-center value for the intended service is exceeded with a bogey device in equipment operating at the stated normal supply voltage.*

*For an AC power source, 117 volts plus or minus 10% is accepted USA practice.

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ABSOLUTE-MAXIMUM RATING SYSTEM

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data, and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, taking no responsibility for equipment variations, environment variations, and the effects of changes in operating conditions due to variations in device characteristics.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in device characteristics.

To illustrate the meaning of these definitions, let us consider an electronic circuit in which it is desired to determine whether the tube employed is operated within the maximum ratings specified for the tube.

If these ratings are presented as design-center ratings, the circuit must be arranged so that it is operating under normal conditions. That is, the supply voltage is adjusted to its normal value, all components employed are selected as average values, the equipment controls are adjusted for normal settings, and the tube employed is selected as a bogey tube. Under these average or most typical conditions, the circuit voltages, currents, and dissipations are measured in turn under the worst signal condition for each particular rating and compared to the specified design-center ratings. If each measured value is less than the corresponding rating and if the equipment is not subjected to supply voltages in excess of the stated variations, the operation of the tube satisfies the conditions of the desing-center system.

On the other hand, if the ratings are presented as absolute-maximum values, the worst probable operating conditions must be established in turn for each item rated. The measurements made with the combination of extreme supply voltage, limit components, extreme control settings, extreme signal, extreme environmental conditions, and any tube which produces the worst probable value for the particular rating under consideration, is compared to the specified absolute-maximum rating. Under these adverse conditions, if each measured value is less than the corresponding rating, the operation of the tube satisfies the conditions of the absolute-maximum system.

These two rating systems differ significantly in the four following aspects:

1. The operating conditions employed in determining whether the tube is operated within maximum ratings

2. The characteristics of the tube employed in determining whether the tube is operated within maximum ratings

3. The permissible excess of the specified values of the maximum ratings

   (Under the absolute-maximum system no excess of the rated value is permitted, while under the design-center system the rated value may be exceeded with adverse operating conditions.)

4. The assignment of basic responsibility for proper tube usage.

   (With the design-center system, the tube manufacturer effectively assumes the responsibility for the effect that both variations in tube characteristics and circuit operating conditions will have on tube performance. On the other hand, under the conditions imposed by the absolute-maximum system, the complete responsibility for variations in tube characteristics and operating conditions is assigned to the circuit designer.)

DIFFICULTIES WITH EXISTING SYSTEMS

Although the design-center system provides the circuit designer with an extremely convenient and usable system, it has the rather severe disadvantage that the degree of protection afforded the tube is variable and depends on the circuit and environmental operating conditions.

Historically this limitation was not particularly significant. The great majority of tubes produced were used in radio receivers which involved essentially standard circuits. Hence the tube manufacturer could be reasonably certain of the effects that a specified line voltage variation would have on the currents, voltages, and dissipations associated with the various tubes employed.

In recent years, however, electronic circuits have become more complex and more diversified. The circuits employed operate under widely different degrees of feedback and supply voltage regulation. As a result a fixed relationship no longer exists between the variations in supply voltage and variations to which the tube is subjected. Two extreme examples in this consideration would be the computer application and the television high-voltage rectifier application.

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In the computer, particular attention is paid to the regulation of heater and plate voltages. Hence normal fluctuation in the supply have little if any effect on tube operating conditions. In the case of the TV flyback high-voltage rectifier, the entire input power including the filament requirements is derived from the horizontal deflection amplifier. All variations in the horizontal-amplifier circuit which can result from variations in sweep tube characteristics, damper tube characteristics, output transformer and other components, and supply voltage, are imposed as variations in the filament power and inverse voltage of the high-voltage rectifier tube. Furthermore the output current required is established by settings of the brightness and contrast controls which in turn depend on the ambient light level of the room in which the receiver operates. All of these various sources contribute to the extreme variations associated with high-voltage rectifier operation. These two examples illustrate the fact that the variations in operating conditions to which a tube can be subjected cannot necessarily be controlled by specifying a permissible variation in supply voltage.

Figure 1 illustrates qualitatively the variation of plate dissipation to which a bogey tube could be subjected in three different circuits, each of which is designed for operation at 100 percent of the maximum-design-center dissipation rating. In each case, the circuit is subjected to $\pm$ 10 percent line voltage variations. The figure illustrates that the degree by which a design-center rating can be exceeded is a function of the circuit and equipment in which the tube is operated.

These considerations indicate that there are at least two disadvantages to the design-center system:

1. The tube manufacturer is not adequately protected. His tubes can be operated within the conditions of the design-center system and yet be subjected to severe operating conditions as typified by Condition C of Figure 1, The design-center system could adequately protect the tube only if standard circuits were used in which known operating variations are encountered.

2. The conservative circuit designer is penalized under the conditions of the design-center system. The system requires only consideration of average operating conditions; no requirements are placed on permissible variation under adverse operating conditions. Consequently no incentive is provided for circuit design which tends to minimize variations applied to the tube. Condition C is as correct as Condition A of Figure 1 according to the rules of the design-center system, yet certainly more satisfactory tube performance would be realized in the latter circuit.

Although the absolute-maximum system is not subject to the shortcomings of the design-center system, it suffers from being extremely difficult to use. Effectively the circuit designer is given the responsibility to keep any tube of the type under consideration from exceeding the absolute-maximum values under worst probable circumstances.

To use the absolute-maximum system the circuit designer must have full knowledge of the tolerances associated with all the variables. He must know the complete range of values which can be encountered with tubes, resistors, ambient temperatures, supply voltages, signal levels, and control settings. To evaluate his tube usage, he must then synthesize the variables in combinations which give rise to the worst probable conditions for each of the rated items.

The problem of selecting components which will combine to produce the worst probable operating conditions is extremely complex. Even in a simple triode circuit, for example, the high limit tube for on plate current is not necessarily the tube which produces the highest plate dissipation. When consideration of the plate dissipation rating is extended to a pentode circuit which incorporates a plate resistor, a screen-dropping resistor, and a cathode-bias resistor, the selection of the necessary tube must be made from tubes which could exhibit maximum plate current/maximum screen current, maximum plate current/minimum screen current, minimum plate current/maximum screen current, minimum plate current/minimum screen current, or a combination in which the currents lie between the limits. The selection cannot be generalized and depends upon the specific application. Furthermore, the particular tube and other components required to evaluate the plate dissipation rating are generally not the same as those required to evaluate the other maximum ratings.

Thus the inherent complexity of selecting and synthesizing limit components and limit tubes, coupled with the practical difficulty in obtaining the required limit tubes, represents the major weakness of the absolute-maximum system, particularly for home or automobile applications without well-regulated power supplies.

As might be expected, the time required to check the conformance of each tube to its specified absolute-maximum ratings in a relatively complicated piece of electronic equipment becomes excessive. Indeed, the practical result is that all too often the evaluation of the tube usage is not rigorously executed. Unfortunately inadequate evaluation can result in the misuse of tubes and the consequent sacrifice in overall equipment performance and reliability.

PRINCIPLES OF THE DESIGN-MAXIMUM SYSTEM

Because of the serious difficulties encountered in the application of the two rating systems in current use, the need for an improved method to express the capabilities of receiving tubes has become increasingly apparent.

Basically the design-center system assigns the entire responsibility for tube usage to the tube manufacturer; he must accept full responsibility for the effects of variations in tube characteristics and variations in any possible circuit operating conditions. The absolute-maximum system assigns this entire responsibility to the circuit designer. A more logical division of these basic responsibilities would be to assign the effect of the variations in tube characteristics to the tube manufacturer and to assign the effects of variations in circuit operating conditions to the equipment manufacturer. This philosophy is incorporated in the Design-Maximum System.

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The design-maximum system requires that the maximum ratings be checked with bogey tubes rather than limit tubes. In this way, the responsibility for variations in tube characteristics is effectively assigned to the tube manufacturer. The task of the circuit designer in determining conformance to the maximum ratings is greatly simplified, and the tube manufacturer is relieved of the almost impossible responsibility for supplying limit tubes to the circuit designer for his maximum rating evaluation.

This system also requires that the specified maximum ratings not be exceeded when the circuit is so arranged that the bogey tube is operated under the worst probable conditions. In this way the responsibility for variations in operating conditions is effectively assigned to the circuit designer. He must realistically anticipate the worst probable operating conditions likely to be encountered for each tube in his equipment.

In a television receiver, for example, it is possible -- particularly at high line -- to exceed some of the ratings in certain stages by very great amounts when the controls are completely maladjusted. However, if the maladjustment of controls makes the picture unusable, the probability of this condition occurring for a prolonged period is remote as the receiver would normally be turned off. The worst probable operating conditions resulting from control setting would occur when the controls were maladjusted only to the extent that a minimum usable picture could still be obtained.

Another example of worst probable conditions occurs in the case of rectifier output current. In this case, particularly if the load consists of an appreciable number of tubes, the difference in output current required between the probable high load and the theoretical maximum load is very large. Again the significant value from the standpoint of proper usage of the rectifier tube is the worst probable load current.

Therefore, under the design-maximum system, the tube manufactuer in effect supplies the circuit designer with maximum limiting values based on bogey tubes. Because some variation in circuit operating conditions is present in any practical circuit, the equipment manufacturer must design his equipment below the design-maximum values so that no one of these ratings will be exceeded under the worst probable operating conditions which will be encountered. The degree to which the circuit must be designed below the design-maximum ratings depends on the extent to which the variables are controlled in the equipment.

Inherently, the proposed design-maximum system requires that the circuit designer anticipate the adverse conditions to which his equipment will be subjected. The circuit designer is the person to whom this responsibility should be delegated. Also the equipment manufacturer must assume the risk whenever bogey tubes are operated above the design-maximum ratings.

It must be recognized that in some rare instances a tube which is operated at its design-maximum ratings under the worst probable operating conditions could exceed the ratings under unanticipated or freak conditions. For optimum design, therefore, the circuit designer must discriminate on a statistical basis between unlikely operation and adverse operation which can reasonably be expected to occur. The degree of risk which the equipment manufacturer could reasonably assume in this connection would necessarily depend on the reliability requirements of the final equipment. How competently the circuit designer evaluates his tube usage will be reflected in the final overall performance of the equipment.

The foregoing concepts are summarized in the following definition:

DESIGN-MAXIMUM RATING SYSTEM

Design-Maximum ratings are limiting values of operating and environmental conditions applicable to a bogey electron device of a specified type as defined by its published data, and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, taking responsibility for the effects of changes in operating conditions due to variations in device characteristics.

The equipment manufacturer should design so that initially and throughout life no design-maximum value for the intended service is exceeded with a bogey device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, and environmental conditions.

Not included in the definition is any reference to the permissible heater or filament voltage variation. Actually, the conditions of the design-maximum system in no way restrict the heater or filament voltage tolerance. For this reason, no fixed tolerance is included in the fundamental definition; the permissible variation in heater or filament voltage will be specified for each individual tube type.

It should also be noted that the design-maximum rating system overcomes the fundamental difficulties associated with the two existing systems. As opposed to the design-center system, incentive is provided to the circuit designer to study and control the variations in operating conditions to which the tubes are subjected. The tube manufacturer is fully responsible for control of quality in areas in which he operates, but is not responsible for those areas which he can neither evaluate nor control. As compared to the absolute-maximum ratings, design-maximum ratings are significantly simpler to use. The principles of the design-maximum rating system can be applied to such diverse classes of service as television receivers, computers, military equipment, and industrial equipment.

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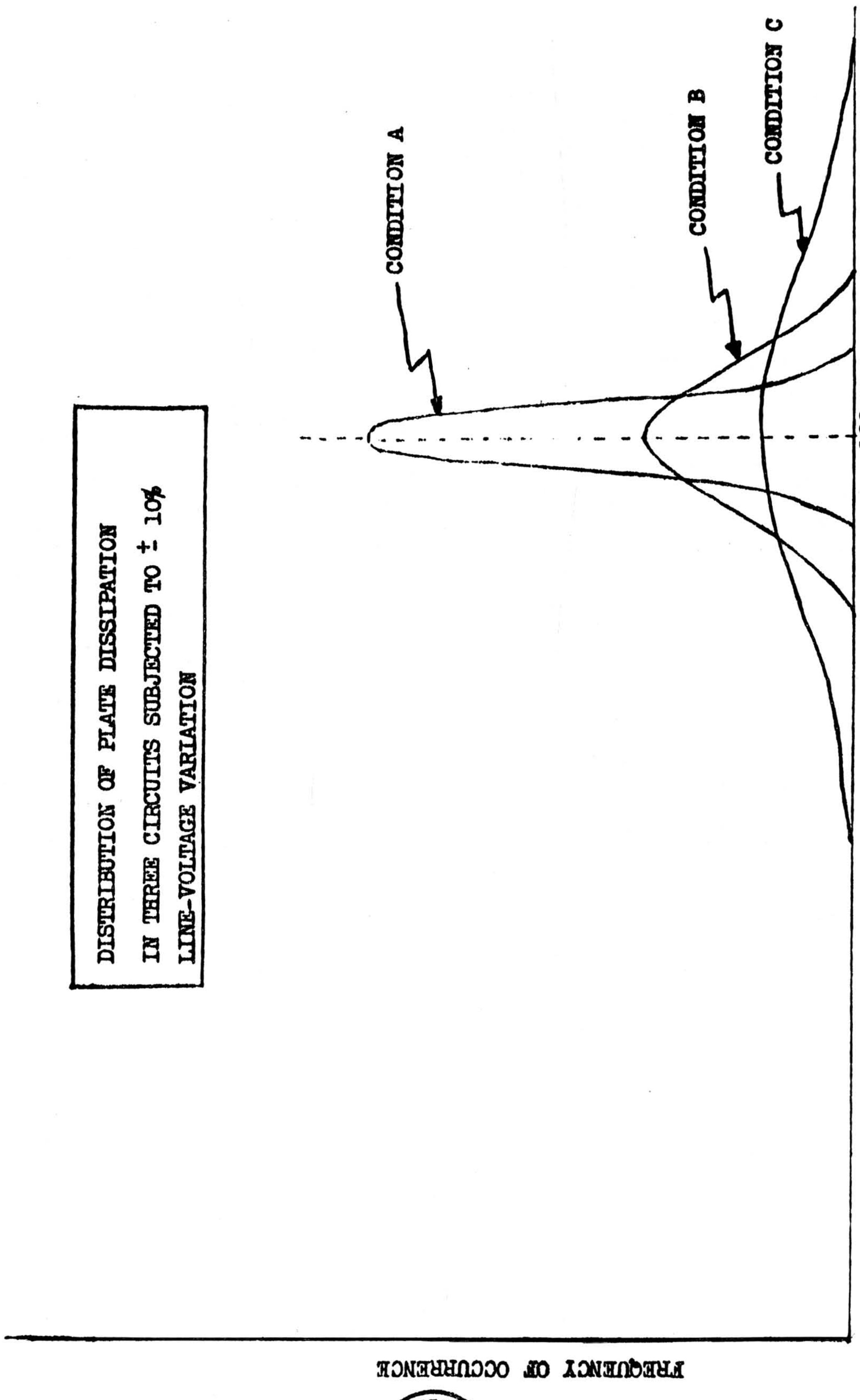

FIGURE 1 - PLATE DISSIPATION AS PERCENT OF DESIGN-CENTER RATING

THE APPLICATION OF THE DESIGN-MAXIMUM SYSTEM TO CIRCUIT DESIGN EVALUATION

GENERAL

The foregoing discussion of the Design-Maximum Rating System clearly pointsout the present-day need for the new rating system. The tube manufacturers' and equipment manufacturers' responsibilities are defined as related to the serviceability and dependability of the final product. The following general information will be useful for the correct application and interpretation of design-maximum ratings in circuit design evaluation.

BOGEY TUBE

A bogey tube in the exact sense would be a tube of a specified type which has each and all of its characteristics equal to the published values. Such a tube is extremely difficult to find because of the large number of characteristics involved. For practical purposes of application, a bogey tube can be obtained by considering only those characteristics which are directly related to the class of service being evaluated.

Suggested procedures to be followed in applying the design maximum system to several classes of service will be found on the pages which follow. The particular conditions described are those which contribute the major portion to the worst probable operating conditions. Significant variations may occur in other conditions and components such as power transformers, filament transformers, load current demand, etc. Those should be considered so as to comply with the definition of the Design-Maximum System. In each example the qualifications for the "bogey tube" to be used are clearly pointed out at the beginning of each section.

RANGES OF SUPPLY VOLTAGES

Various industry and government groups have standardized on ranges of supply voltages to be used in evaluating equipment performance. For the purpose of applying the Design-Maximum Rating System to circuit design evaluation, the following ranges will be used:

AC Line Operated Equipment

Low Line Voltage	Center Line Voltage	High Line Voltage
105 volts	117 volts	129 volts

Automotive Equipment

	Low Battery	High Battery
6 volt System	5.0 volts	8.0 volts
12 volt System	10.0 volts	15.9 volts

Dry Battery Operated Equipment

	Minimum Voltage	Maximum Voltage
"A" Battery (1.5V. Cell)	1.1 volts	1.6 volts
"B" Battery	--	Rated Block Voltage ± 10%

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CLASS A, SMALL-SIGNAL AMPLIFIERS*

SCOPE:

This example applies the Design-Maximum Rating System to tubes used as RF and IF amplifiers in AC line operated equipment.

BOGEY TUBE SELECTION:

A bogey tube shall be one which exhibits plate current, grid #2 current and cutoff voltage approximately equal to the values listed in the "Average Characteristics" and/or "Typical Operation" section of the registered data.

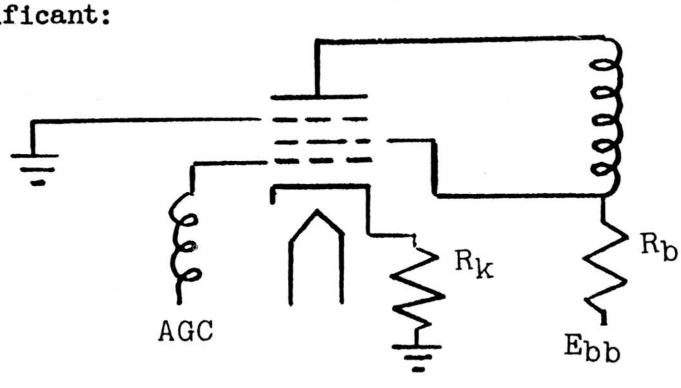
TUBE RATINGS:

To assure operation within the design-maximum ratings, the equipment designer should evaluate the application of the tube against all of the ratings listed in the registered data. In general, the following items will be included:

Heater voltage
Maximum plate voltage
Maximum grid #2 voltage
Maximum plate dissipation
Maximum grid #2 dissipation
Maximum negative grid #1 voltage
Maximum positive grid #1 voltage
Maximum heater-cathode voltage

CIRCUIT AND OPERATING CONSIDERATIONS:

Before a circuit designer can evaluate his application for conformance with the ratings, he must ascertain those parameters which will contribute to the worst probable operating conditions. For example, in the circuit shown, the following variables are significant:



Line Voltage - An increase in line voltage will increase plate voltage, grid #2 voltage, heater-cathode voltage, plate dissipation, and grid #2 dissipation. Low and high line voltages will determine the operating range of the heater.

Cathode Resistor (Rk) - A low value of cathode resistance will increase the plate and grid #2 dissipation. A high value of cathode resistance may contribute to an increased heater-cathode voltage.

Series Dropping Resistor (Rb) - A low value of resistance will increase plate voltage, grid #2 voltage, plate dissipation and grid #2 dissipation.

AGC Voltage - The maximum AGC voltage will increase the plate voltage, grid #2 voltage and negative grid #1 voltage. The minimum AGC voltage will increase plate dissipation, grid #2 dissipation and may cause grid #1 voltage to become positive. The AGC voltage may also contribute to variations in heater-cathode voltage.

PROCEDURE FOR EVALUATION:

1. Set up the equipment under the following conditions:

   a. Bogey tube in the circuit being evaluated
   b. Resistor Rk at the minimum value normally encountered
   c. Resistor Rb at the minimum value normally encountered
   d. Supply voltage at high line (129 volts)
   e. AGC voltage at minimum bias normally anticipated

2. Measure:

   a. Heater voltage
   b. Plate dissipation
   c. Grid #2 dissipation
   d. Grid #1 voltage

3. Adjust AGC voltage to maximum value normally anticipated with other conditions remaining the same as in Step 1.

4. Measure:

   a. Plate voltage
   b. Grid #2 voltage
   c. Grid #1 voltage

5. Replace resistor Rk with a resistor at the maximum value normally encountered with other conditions remaining the same as in Step 3.

6. Vary AGC voltage and measure both DC and peak values of heater-cathode voltage at both polarities. Record highest values.

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7. Reduce supply voltage to low line (105 volts), set AGC to a convenient level with other conditions remaining the same as in Step 5.

8. Measure:

   a. Heater voltage

9. Compare all items measured (Steps 2, 4, 6, and 8) with the ratings listed in the registered data. If all items are within the maximum and minimum values specified, the tube is operating within its ratings. If any one rating is exceeded, the tube is operating beyond its ratings.

*Note: The detailed procedure for evaluation presented in this section necessarily applies only to the specific circuit configuration indicated. For other circuit configurations, appropriate modifications will be required; these modifications can be determined by applying the basic philosophy underlying the above procedures--that is, each maximum rating should be evaluated with a bogey tube under the worst probable combination of circuit variables.

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CLASS A, POWER AMPLIFIERS*

SCOPE:

This example applies the Design-Maximum Rating System to tubes used as Class A Power Amplifiers in automotive equipment.

BOGEY TUBE SELECTION:

A bogey tube shall be one which exhibits zero-signal plate current, and maximum signal power output approximately equal to the values listed in "Typical Operating Conditions and Characteristics, Class A1 Amplifier (Single Tube)" section of the registered data, for the particular set of conditions most closely related to the application to be evaluated. Zero-signal grid #2 current should be reasonably close to the rated value.

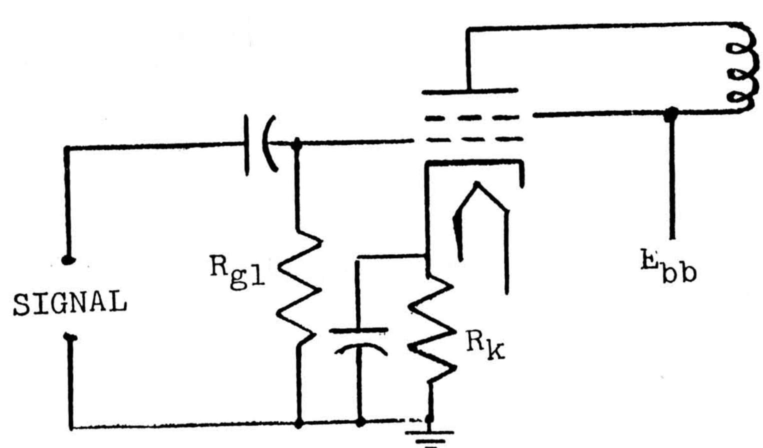
TUBE RATINGS:

To assure operation within the design-maximum ratings, the equipment designer should evaluate the application of the tube against all of the ratings listed in the registered data. In general, the following items will be included:

Heater voltage
Maximum plate voltage
Maximum grid #2 voltage
Maximum plate dissipation
Maximum grid #2 dissipation
Maximum heater-cathode voltage
Maximum grid #1 circuit resistance
Maximum bulb temperature at any point

CIRCUIT AND OPERATING CONSIDERATIONS:

Before a circuit designer can evaluate his application for conformance with the ratings, he must ascertain those parameters which will contribute to the worst probable operating conditions. For example, in the circuit shown, the following variables are significant:



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Supply Voltage - An increase in battery voltage will increase plate voltage, grid #2 voltage, heater-cathode voltage, plate dissipation, grid #2 dissipation, and bulb temperature. Low and high battery voltages will determine the operating range of the heater.

Grid #1 Signal - High signal voltage will incree grid #2 dissipation. Low signal voltage will increase plate voltage, grid #2 voltage and plate dissipation.

Cathode Resistor (Rk) - A low value of cathode resistance will increase plate dissipation, grid #2 dissipation, and bulb temperature. A high value of cathode resistance will increase plate voltage, grid #2 voltage, and may contribute to an increased heater-cathode voltage.

PROCEDURE FOR EVALUATION:

1. Set up the equipment under the following conditions:

   a. Bogey tube in the circuit being evaluated
   b. Supply voltage at high battery (8.0 or 15.9 volts as applicable)
   c. Resistor (Rk) at the minimum value normally encountered
   d. Zero signal

2. Measure:

   a. Heater voltage
   b. Plate dissipation
   c. Bulb temperature (Set shall be enclosed as normally operated. Measure hottest point after one hour of operation).

3. Increase signal to maximum with other conditions remaining the same as in Step 1.

4. Measure:

   a. Grid #2 dissipation

5. Replace resistor (Rk) with a resistor at the maximum value normally encountered with other conditions remaining the same as in Step 3.

6. Measure:

   a. Heater-cathode voltage

7. Reduce signal to zero with other conditions remaining the same as in Step 5.

8. Measure:

   a. Grid #2 voltage
   b. Plate voltage

9. Reduce supply voltage to low battery (5.0 or 10.0 volts, as applicable) with all other conditions remaining the same as in Step 7.

10. Measure:

    a. Heater voltage

11. Remove supply voltage.

12. Measure:

    a. Grid #1 circuit resistance

13. Compare all items (Steps 2, 4, 6, 8, 10, and 12) with the ratings listed in the registered data. If all items are within the maximum and minimum values specified, the tube is operating within its ratings. If any one rating is exceeded, the tube is operating beyond its ratings.

*Note: The detailed procedure for evaluation presented in this section necessarily applies only to the specific circuit configuration indicated. For other circuit configurations, appropriate modifications will be required; these modifications can be determined by applying the basic philosophy underlying the above procedure -- that is, each maximum rating should be evaluated with a bogey tube under the worst probable combination of circuit variables.

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TELEVISION UHF OSCILLATOR*

SCOPE:

This example applies the Design-Maximum Rating System to tubes used as UHF Oscillators in television receivers.

BOGEY TUBE SELECTION:

A bogey tube shall be one which exhibits plate current approximately equal to that as listed in the "Average Characteristics" section, and oscillator grid current approximately equal to that as listed in the "Average Characteristics, UHF Oscillator" section of the registered data.

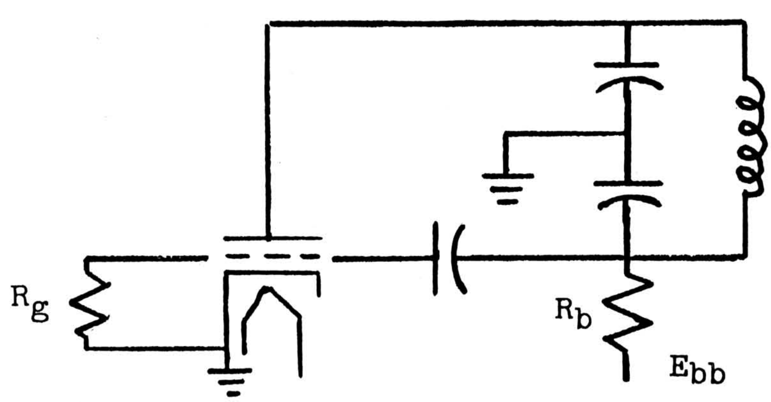
TUBE RATINGS:

To assure operation within the design-maximum ratings, the equipment designer should evaluate the application of the tube against all the ratings listed in the registered data. In general, the following items will be included:

- Heater voltage
- Maximum plate voltage
- Maximum plate dissipation
- Maximum cathode current
- Maximum grid current
- Maximum negative grid voltage
- Maximum heater-cathode voltage

CIRCUIT AND OPERATING CONSIDERATIONS:

Before a circuit designer can evaluate his application for conformance with the ratings, he must ascertain those parameters which will contribute to the worst probable operating conditions. For example, in the circuit shown, the following variables are significant:



Line Voltage - An increase in line voltage will increase plate voltage, heater-cathode voltage, plate dissipation, cathode current and grid current. Low and high line voltages will determine the operating range of the heater.

Plate Dropping Resistor (Rb) - A low value of resistance will increase plate voltage, plate dissipation, cathode current and grid current.

Tuning - Variations in tuning will affect plate voltage, plate dissipation, cathode current, grid current and grid voltage.

PROCEDURE FOR EVALUATION:

1. Set up the equipment under the following conditions:

   a. Bogey tube in the circuit being evaluated
   b. Resistor Rb at the minimum value normally encountered
   c. Supply voltage at high line (129 volts)
   d. Tuning adjusted for maximum cathode current

2. Measure:

   a. Heater voltage
   b. Plate dissipation (the plate dissipation can be considered to approximate the plate input power for this class of service).
   c. Cathode current
   d. Heater-cathode voltage

3. Adjust tuning for maximum grid current with other conditions remaining the same as in Step 1.

4. Measure:

   a. Plate voltage
   b. Grid current
   c. Grid voltage

5. Reduce supply voltage to low line (105 volts) with other conditions remaining the same as in Step 3.

6. Measure:

   a. Heater voltage

7. Compare all items measured (Steps 2, 4, and 6) with the ratings listed in the registered data. If all items are within the maximum and minimum values specified, the tube is operating within its ratings. If any one rating is exceeded, the tube is operating beyond its ratings.

Note: The detailed procedure for evaluation presented in this section necessarily applies only to the specific circuit configuration indicated. For other circuit configurations, appropriate modifications will be required; these modifications can be determined by applying the basic philosophy underlying the above procedure -- that is, each maximum rating should be evaluated with a bogey tube under the worst probable combination of circuit variables.

JOINT ELECTRON TUBE ENGINEERING COUNCIL

POWER RECTIFIERS

SCOPE:

This example applies the Design-Maximum Rating System to tubes used as rectifiers for "B" power supplies in AC line operated equipment.

BOGEY TUBE SELECTION:

A bogey tube shall be one which exhibits tube voltage drop approximately equal to the value shown in the "Ratings" section of the registered data.

TUBE RATINGS:

To assure operation within the design-maximum ratings, the equipment designer should evaluate the application of the tube against all the ratings listed in the registered data. In general, the following items will be included:

- Heater or filament voltage
- Maximum peak inverse voltage
- Maximum AC plate supply voltage
- Maximum DC output current
- Maximum steady state peak plate current
- Maximum transient peak plate current
- Maximum heater cathode voltage
- Mounting position
- Bulb temperature

CIRCUIT AND OPERATING CONSIDERATIONS:

Before a circuit designer can evaluate his application for conformance with the ratings, he must ascertain those parameters which will contribute to the worst probable operating conditions. For example, in the typical full wave rectifier circuit, the following variables are significant:

Line Voltage - An increase in line voltage will increase AC plate voltage, peak inverse plate voltage, DC output current, both steady state and transient peak plate current and heater-cathode voltage. Low and high line voltage will determine the operating range of the filament or heater.

Input Filter Capacitance - An increase in input filter capacitance will increase peak and steady state plate currents, DC output current and peak inverse voltage.

Resistance of Load - If increased, will increase the peak inverse voltage while if decreased will raise the DC output, and the steady state peak currents. Low load resistance will cause transient peak plate currents to flow for a longer period.

Series Impedance - If decreased will result in an increase of steady state and transient peak plate currents, DC output current and peak inverse voltage.

Environment - Will affect the operating temperature of the tube. An effort should be made to provide adequate ventilation for the rectifier tube and to have its mounting position in agreement with the registered data.

PROCEDURE FOR EVALUATION:

1. Set up the equipment under the following conditions:

   a. Bogey tubes in the circuit under evaluation
   b. Power transformer selected for minimum equivalent series impedance normally encountered
   c. Series plate resistor, if used, selected at the minimum value normally encountered
   d. Input filter capacitor with the maximum leakage and capacitance normally encountered
   e. Other equipment components and adjustments set to produce a maximum output current loading
   f. Supply voltage at high line (129 volts)

2. Measure:

   a. DC output current
   b. Peak steady state plate current
   c. Peak transient peak plate current (this should be observed while switching the equipment on and off several times).
   d. Bulb temperature (this should be read after temperature is stabilized and with all enclosures, cabinets, etc., in place).

3. Reduce supply voltage to low line (105 volts).

4. Measure heater or filament voltage.

5. With no change in rectifier circuit components change any other equipment components or adjustments to the limits of their normally expected ranges which will result in a reduction of recitifier output current. Adjust the line voltage to high line (129 volts).

6. Measure:

   a. Peak inverse plate voltage
   b. Heater or filament voltage
   c. Heater-cathode voltage
   d. RMS AC plate supply voltage

7. Compare all items measured (Steps 2, 4, and 6) with ratings or charts listed in the registered data. If all items are within the maximum and minimum values specified, the tube is operating within its ratings. If any one rating is exceeded, the tube is operating beyond its ratings.

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TELEVISION HORIZONTAL DEFLECTION CIRCUITS*

SCOPE:

This example applies the Design-Maximum Rating System to tubes used as Horizontal Deflection Oscillators, Horizontal Deflection Amplifiers, Damper Diodes and High Voltage Rectifiers.

These horizontal deflection system tubes should be evaluated as a group because of their interdependent relationships.

BOGEY TUBE SELECTION:

For each application, a bogey tube shall be one which exhibits characteristics approximately equal to the values listed in the "Average Characteristics" and/or the "Typical Operation" sections of the registered data as follows:

A. Horizontal Deflection Amplifier

1. Peak plate current at zero bias
2. Peak grid #2 current at zero bias
3. Grid #1 cut off voltage

Note: Plate and grid #2 currents under condition at which Gm is measured should be reasonably close to rated values.

B. Damper Diode

1. Tube voltage drop

C. Horizontal Deflection Oscillator

1. Plate current under conditions at which Gm is measured
2. Grid #1 cut off voltage

D. High Voltage Rectifier

1. Filament current
2. Tube voltage drop should be reasonable, although it is not too critical.

TUBE RATINGS:

To assure operation within the design-maximum ratings, the equipment designer should evaluate the application of the tube against all the ratings listed in the registered data. In general, the following items will be included for each class of service:

A. Horizontal Deflection Amplifier

Heater voltage
Maximum DC plate supply voltage (Boost + DC power supply)
Maximum peak positive plate voltage
Maximum peak negative plate voltage
Maximum plate dissipation
Maximum peak negative #1 voltage
Maximum grid #2 voltage
Maximum grid #2 dissipation
Maximum average cathode current
Maximum peak cathode current
Maximum grid #1 circuit resistance
Maximum bulb temperature (at hottest point)
Maximum heater-cathode voltage

B. Damper Diode

Heater voltage
Maximum peak inverse plate voltage
Maximum DC plate current
Maximum peak plate current
Maximum plate dissipation
Maximum heater-cathode voltage

C. Horizontal Deflection Oscillator

Heater voltage
Maximum DC plate voltage
Maximum plate dissipation
Maximum peak negative grid voltage
Maximum average cathode current
Maximum peak cathode current
Maximum grid circuit resistance
Maximum heater-cathode voltage

D. High Voltage Rectifier (Flyback)

Filament voltage
Maximum inverse plate voltage
Maximum peak plate current
Maximum average plate current

CIRCUIT AND OPERATING CONSIDERATIONS:

Before a circuit designer can evaluate his application for conformance with the ratings, he must ascertain those parameters which will contribute to the worst probable operating conditions. For example, in the circuit shown, the following variables are significant:

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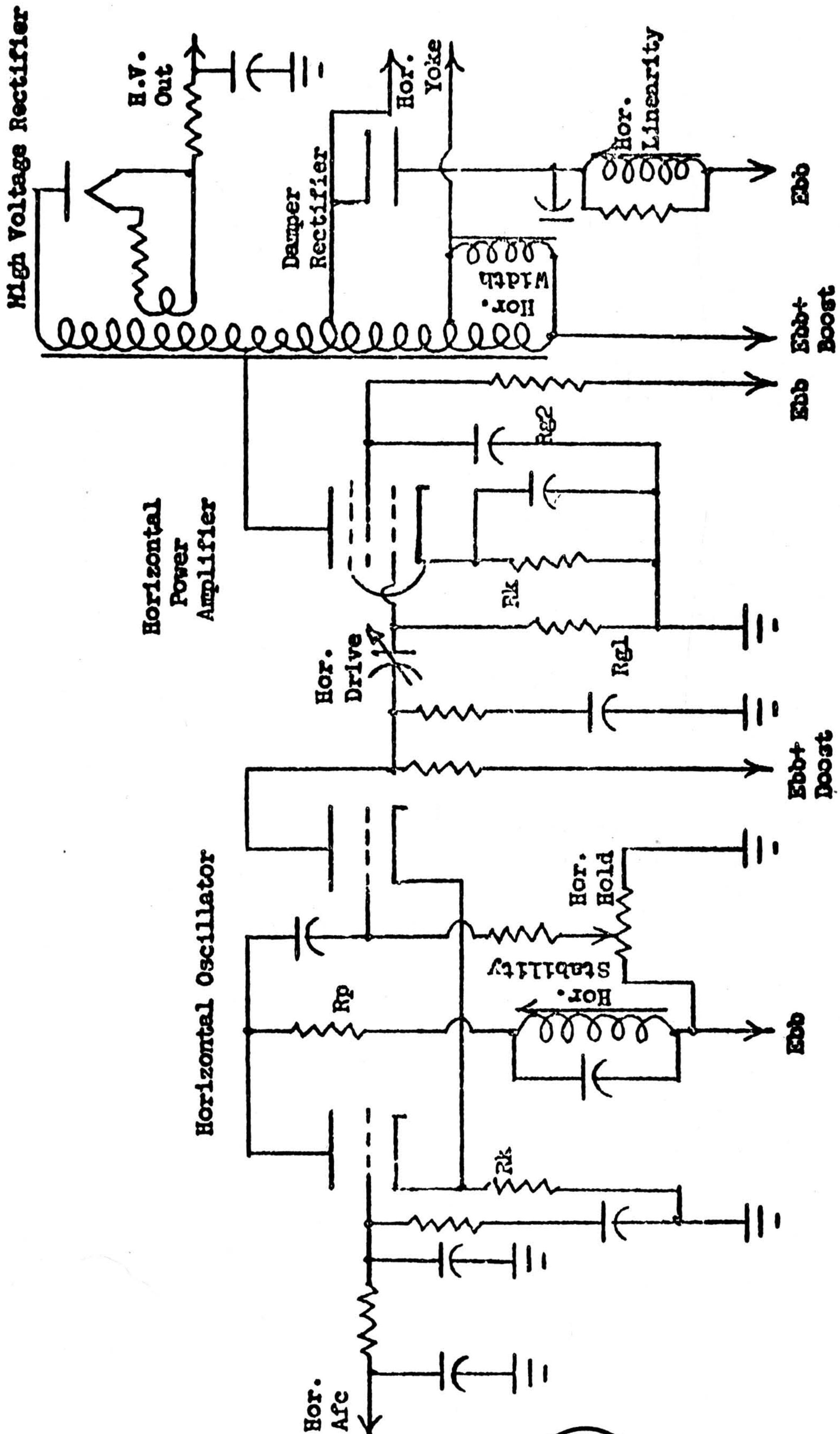

HORIZONTAL DEFLECTION CIRCUIT

Line Voltage - An increase in line voltage will generally increase all element voltages, currents, dissipations and bulb temperatures for tubes in the horizontal deflection system. Low and high line voltages will determine the operating range of the heater.

Cathode Resistor (Rk) - A low value of resistance will increase the plate and grid #2 dissipation and may increase the plate and grid #2 to cathode voltages. A high value of cathode resistance may contribute to an increased heater-cathode voltage.

Grid #2 Dropping Resistor (Rg2) - A low value of resistance will increase all voltages, currents and dissipations affected by the boosted plate supply voltage,and will increase the screen dissipation of the horizontal deflection amplifier.

Plate Lead Resistor (Rp) - A low value of resistance will increase plate voltage, plate dissipation and peak and average cathode currents.

Horizontal Amplifier Grid Drive - An increase in amplitude of grid drive on the horizontal deflection amplifier will increase the peak grid #1 and plate voltages and the screen dissipation of this tube. It will also increase the boosted plate supply voltage and all other voltages tied there. Currents and dissipations of some tubes tied to the boost may be increased, but the average cathode currents and the plate dissipations of the horizontal deflection amplifier and the damper rectifier will decrease. Also, as the horizontal drive is increased, the peak inverse voltage (both pulse and DC components), the average and peak currents, and the filament voltage, all will increase on the high voltage rectifier.

A decrease in amplitude of grid drive on the horizontal deflection amplifier usually will increase the plate dissipation, grid #2 voltage, average cathode current, and bulb temperature of this tube and the damper rectifier, but generally, all other voltages, currents, and dissipations will decrease.

Width Control - The inductive shunt type width control changes the load characteristics and helps to determine the minimum plate voltage swing of the horizontal deflection amplifier. Thus, as the shunting inductance is decreased in this circuit, the width is decreased and the plate dissipation, average cathode current and bulb temperature will increase on that tube. Otherwise, all currents, voltages and dissipations for the horizontal deflection system tubes will usually increase as the width is increased.

Brightness Control - An increase in brightness will increase the average and peak plate currents of the high voltage rectifier, but will decrease the peak inverse voltage.

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Yoke Inductance - This has the same effect on the horizontal deflection tube operating conditions as does the inductive width control. (See previous).

Miscellaneous - The horizontal hold control has little effect on the operating characteristics of the tubes in the horizontal deflection system except as it affects the amplitude of the horizontal drive (see previous) and as it may affect the operating conditions of the horizontal oscillator tube.

The horizontal linearity control can cause a serious increase in plate dissipation of the damper rectifier.

Variations in AFC circuits components may affect the amplitude of the horizontal drive (see previous).

Variations in the horizontal fly-back transformer should be considered if adequate compensation cannot be made by adjustment of drive, width and linearity controls.

The AGC voltage, and other set adjustments only affect the tubes in the horizontal deflection system as they affect the plate supply voltage of the equipment and are usually of little consequence.

PROCEDURE FOR EVALUATION:

A. Horizontal Deflection Amplifier

1. Set up the equipment under the following conditions:

   a. Bogey tube in the circuit being evaluated
   b. Supply voltage at high line (129 volts)
   c. Resistors Rk and Rg2 of the horizontal deflection amplifier at the minimum values normally encountered
   d. Grid #1 drive voltage adjusted for maximum normally encountered
   e. Width control at maximum
   f. Yoke inductance at maximum
   g. Brightness control at minimum normally encountered
   h. Linearity control at normal adjustment
   i. Items discussed previously under "Miscellaneous" should be adjusted according to their effects on the tube ratings being evaluated in the particular circuit.

2. Measure:

   a. Heater voltage
   b. DC plate supply voltage (boost + DC power supply)
   c. Peak positive plate voltage
   d. Peak negative plate voltage
   e. Peak negative grid #1 voltage
   f. DC grid #2 voltage
   g. Grid #2 dissipation
   h. Peak cathode current

3. With other conditions the same as in Step 1, make the following changes in adjustment:

   a. Grid #1 drive voltage at minimum normally encountered
   b. Width control at minimum
   c. Yoke inductance at minimum
   d. Linearity control adjusted for maximum average cathode current in horizontal deflection amplifier that is compatible with a usable picture

4. Measure:

   a. Plate dissipation
   b. DC grid #2 voltage
   c. Average cathode current
   d. Bulb temperature

5. With other conditions the same as in Step 3, increase Rk to the maximum value normally encountered.

6. Measure:

   a. Heater-cathode voltage

7. Reduce supply voltage to low line (105 volts) with other conditions remaining the same as in Step 3.

8. Measure:

   a. Heater voltage

9. Compare all items measured (Steps 2, 4, 6, and 8) with the ratings listed in the registered data. If all items are within the maximum and minimum values specified, the tube is operating within its ratings. If any one rating is exceeded, the tube is operating beyond its ratings.

B. Damper Diode

1. Set up the equipment under the following conditions:

   a. Bogey tube in the circuit being evaluated
   b. Supply voltage at high line (129 volts)
   c. Resistors Rk and Rg2 of the horizontal deflection amplifier at the minimum values normally encountered
   d. Grid #1 drive voltage of the horizontal deflection amplifier adjusted for maximum normally encountered
   e. Width control at maximum
   f. Yoke inductance at maximum
   g. Brightness control at minimum normally encountered
   h. Linearity control at normal adjustment
   i. Items discussed previously under "Miscellaneous" should be adjusted according to their effects on the tube ratings being evaluated in the particular circuit.

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2. Measure:

   a. Heater voltage
   b. Peak inverse plate voltage (DC and pulse components)
   c. Peak plate current
   d. Heater-cathode voltage (DC and peak)

3. With other conditions the same as in Step 1, make the following changes in adjustment:

   a. Grid #1 drive voltage of the horizontal deflection amplifier at minimum normally encountered
   b. Width control at minimum
   c. Yoke inductance at minimum
   d. Linearity control adjusted for maximum DC plate current in the damper diode that is compatible with a usable picture.

4. Measure:

   a. DC plate current
   b. Plate dissipation

5. Reduce supply voltage to low line (105 volts) with the other conditions remaining the same as in Step 3.

6. Measure:

   a. Heater voltage

7. Compare all items measured (Steps 2, 4, and 6) with the ratings listed in the registered data. If all items are within the maximum and minimum values specified, the tube is operating within its ratings. If any one rating is exceeded, the tube is operating beyond its ratings.

C. <u>Horizontal Deflection Oscillator</u>

1. Set up the equipment under the following conditions:

   a. Bogey tube in the circuit being evaluated
   b. Supply voltage at high line (129 volts)
   c. Resistors Rk and Rg2 of the horizontal deflection amplifier at the minimum values normally encountered.
   d. Resistors Rk and Rp of the horizontal oscillator circuit at the minimum values normally encountered.
   e. Grid #1 drive voltage of the horizontal deflection amplifier adjusted for maximum normally encountered.
   f. Boosted plate supply voltage at maximum usually encountered.
   g. Items discussed previously under "Miscellaneous" should be adjusted according to their effects on the tube ratings being evaluated in the particular circuit.

2. Measure:

   a. Heater voltage
   b. DC plate voltage
   c. Plate dissipation
   d. Peak negative grid voltage
   e. Average cathode current
   f. Peak cathode current

3. With other conditions the same as in Step 1, increase Rk of the horizontal deflection oscillator to the maximum value normally encountered.

4. Measure:

   a. Heater-cathode voltage

5. Reduce supply voltage to low line (105 volts) with the other conditions remaining the same as in Step 3.

6. Measure:

   a. Heater voltage

7. Compare all items measured (Steps 2, 4, and 6) with the ratings listed in the registered data. If all items are within the maximum and minimum values specified, the tube is operating within its ratings. If any one rating is exceeded, the tube is operating beyond its ratings.

D. <u>High Voltage Rectifier</u>

1. Set up the equipment under the following conditions:

   a. Bogey tube in the circuit being evaluated
   b. Supply voltage at high line (129 volts)
   c. Resistors Rk and Rg2 of the horizontal deflection amplifier at the minimum values normally encountered.
   d. Grid #1 drive voltage adjusted for maximum normally encountered.
   e. Width control at maximum
   f. Yoke inductance at maximum
   g. Brightness control at minimum normally encountered
   h. Linearity control at normal adjustment
   i. Items discussed previously in "Miscellaneous" should be adjusted according to their effects on the tube ratings being evaluated in the particular circuit.

2. Measure:

   a. Filament voltage
   b. Inverse plate voltage (DC and pulse)

3. Increase brightness to maximum with other conditions remaining the same as in Step 1.

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4. Measure:

   a. Average plate current
   b. Peak plate current

5. With other conditions the same as in Step 3, make the following changes in adjustments:

   a. Reduce supply voltage to low line (105 volts)
   b. Grid #1 drive voltage on the horizontal deflection amplifier at minimum normally encountered.
   c. Width control at minimum
   d. Yoke inductance at minimum
   e. Linearity control adjusted for maximum average cathode current in horizontal deflection amplifier that is compatible with a usable picture.

6. Measure:

   a. Filament voltage

7. Compare all items measure (Steps 2, 4, and 6) with the ratings listed in the registered data. If all items are within the maximum and minimum values specified, the tube is operating within its ratings. If any one rating is exceeded, the tube is operating beyond its ratings.

*Note: The detailed procedure for evaluation presented in this section necessarily applies to the specific circuit configuration indicated. For other circuit configurations, appropriate modifications will be required; these modifications can be determined by applying the basic philosophy underlying the above procedure -- that is, each maximum rating should be evaluated with a bogey tube under the worst probable combination of circuit variables.