TUBE RATINGS

AND THEIR SIGNIFICANCE

A rating is a designation, as established by definite standards, of an operating limit of a tube. Tubes are rated by either of two systems, i.e., the "absolute maximum" system or the "design-center maximum" system. Of the two, the absolute maximum system is the older and dates back to the beginning of tubes. With either system, each maximum rating for a given tube type must be considered in relation to all other maximum ratings for that type, so that no one maximum rating will be exceeded in utilizing any other maximum rating. For convenience in referring to these two systems, the former will hereinafter be called the "absolute system," and the latter, the "design-center system."

In the absolute system,* the maximum ratings shown for each type thus rated are limiting values above which the serviceability of the tube may be impaired from the viewpoint of life and satisfactory performance. Therefore, in order not to exceed these absolute ratings, the equipment designer has the responsibility of determining an average design value for each rating below the absolute value of that rating by an amount such that the absolute values will never be exceeded under any usual condition of supply-voltage variation, load variation, or manufacturing variation in the equipment itself.

The equipment should be designed to operate the filament or heater of each tube type at rated normal value for full-load operating conditions under average voltage-supply conditions. Variations from this normal value due to voltage-supply fluctuation or other causes, should not exceed ±5 per cent unless otherwise specified by the tube manufacturer.

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* Types rated according to the absolute system have no identification on their data pages issued prior to April 1, 1942. Sheets issued after that date carry the statement "Maximum Ratings Are Absolute Values" preceding the ratings.

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In the **design-center system**** adopted by the receiving-tube industry late in 1939, the maximum ratings shown for each type thus rated are working design-center maximums. The basic purpose underlying this system is to provide satisfactory average performance in the greatest number of equipments on the premise that they will not be adjusted to local power-supply conditions at time of installation. In the setting up of design-center ratings, consideration has been given to three important kinds of power supply commonly in use, i.e., a-c and d-c power lines, storage battery with connected charger, and dry batteries.

In the case of a-c or d-c power lines, the maximum ratings for tubes rated according to the design-center system have been chosen so that the tubes will give satisfactory performance at these maximum ratings in equipment operated from power-line supplies whose normal voltage including normal variations fall within ±10 per cent of a specified center value. In other words, it is basic to the design-center system of ratings for tubes operated from power-line supplies that filaments or heaters as well as positive- and negative-potential electrodes may have to operate at voltages differing as much as ±10 per cent from their rated values. It also recognizes that equipment may occasionally be used on power-line supplies outside the normal range, but since such extreme cases are the exception, they should be handled by adjustment made locally.

The choice of ±10 per cent takes care of voltage differences in power lines in the U.S.A. where surveys have shown that the voltages delivered fall within ±10 per cent of 117 volts. Therefore, satisfactory performance from tubes rated according to the design-center system will ordinarily be obtained

** Types rated according to the **design-center system** are identified on their data pages either by a large star in the index corner or by the statement "Maximum Ratings Are Design-Center Values" preceding the ratings. This statement is used on sheets issued since April 1, 1942.

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anywhere in the U.S.A. in equipment designed so that the design-center maximum ratings are not exceeded at a line-voltage-center value of 117 volts. While 117 volts represents present-day conditions, the design-center system permits the utilization of a new line-center value as new surveys may indicate the necessity for such a change.

In the case of storage-battery-with-charger supply or similar supplies, the normal battery-voltage fluctuation may be as much as 35 per cent or more. This fluctuation imposes severe operating conditions on tubes. Under these conditions, latitude for operation of tubes is provided for by the stipulation that only 90 per cent of the design-center maximum values of plate voltages, screen-supply voltages, dissipations, and rectifier output currents is never exceeded for a terminal potential at the battery source of 2.2 volts per cell. While a tube's operating voltages in this service will at times exceed the maximum values, satisfactory performance with probable sacrifice in life will be obtained.

In the cases of dry-battery supply and rectified a-c supply for 1.4-volt tubes, recommended design practice is given in RMA Standard M8-210.

RMA Standard M8-210 (Jan. 8, 1940 Rev. 11-40) is reproduced here for the convenient reference of design engineers with permission of the Engineering Department of the Radio Manufacturers Association. Although worded to cover only receiving tubes, it can be applied to any tube having design-center-system ratings.

* * *

It shall be standard to interpret the ratings on receiving types of tubes according to the following conditions:

1. CATHODE—The heater or filament voltage is given as a normal value unless otherwise stated. This means that transformers or resistances in the heater or filament circuit should be designed to op-

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erate the heater or filament at rated value for full-load operating conditions under average supply-voltage conditions. A reasonable amount of leeway is incorporated in the cathode design so that moderate fluctuations of heater or filament voltage downward will not cause marked falling off in response; also, moderate voltage fluctuations upward will not reduce the life of the cathode to an unsatisfactory degree.

A. 1.4-Volt Battery Tube Types—The filament power supply may be obtained from dry-cell batteries, from storage batteries, or from a power line. With dry-cell battery supply, the filament may be connected either directly across a battery rated at a terminal potential of 1.5 volts, or in series with the filaments of similar tubes across a power supply consisting of dry cells in series. In either case, the voltage across each 1.4-volt section of filament should not exceed 1.6 volts. With power-line or storage-battery supply, the filament may be operated in series with the filaments of similar tubes. For such operation, design adjustments should be made so that, with tubes of rated characteristics, operating with all electrode voltages applied and on a normal line voltage of 117 volts, or on a normal storage-battery voltage of 2.0 volts per cell (without a charger) or 2.2 volts per cell (with a charger), the voltage drop across each 1.4-volt section of filament will be maintained within a range of 1.25 to 1.4 volts with a nominal center of 1.3 volts. In order to meet the recommended conditions for operating filaments in series from dry-battery, storage-battery, or power-line sources it may be necessary to use shunting resistors across the individual 1.4-volt sections of filament.

B. 2.0-Volt Battery Tube Types—The 2.0-volt line of tubes is designed to be operated with 2.0 volts across the filament. In all cases the operat-

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ing voltage range should be maintained within the limits of 1.8 volts to 2.2 volts.

2. POSITIVE POTENTIAL ELECTRODES — The power sources for the operation of radio equipment are subject to variations in their terminal potential. Consequently, the maximum ratings shown on the tube-type data sheets have been established for certain Design Center Voltages which experience has shown to be representative. The Design Center Voltages to be used for the various power supplies together with other rating considerations are as given below:

A. AC or DC Power Line Service in U.S.A.—The design center voltage for this type of power supply is 117 volts. The maximum ratings of plate voltages, screen-supply voltages, dissipations, and rectifier output currents are design maximums and should not be exceeded in equipment operated at a line voltage of 117 volts.

B. Storage-Battery Service—When storage-battery equipment is operated without a charger, it should be designed so that the published maximum values of plate voltages, screen-supply voltages, dissipations, and rectifier output currents are never exceeded for a terminal potential at the battery source of 2.0 volts per cell. When storage-battery equipment is operated with a charger, it should be designed so that 90% of the same maximum values is never exceeded for a terminal potential at the battery source of 2.2 volts.

C. "B"-Battery Service—The design center voltage for "B" batteries is the normal voltage rating of the battery block, such as 45 volts, 90 volts, etc. Equipment should be designed so that under no condition of battery voltage will the plate voltages, the screen-supply voltages, or dissipations ever exceed the recommended respective maximum values shown in the data for each tube type by more than 10%.

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D. Other Considerations

a. Class A_1 Amplifiers—The maximum plate dissipation occurs at the "Zero-Signal" condition. The maximum screen dissipation usually occurs at the condition where the peak-input signal voltage is equal to the bias voltage.

b. Class B Amplifiers—The maximum plate dissipation theoretically occurs at approximately 63% of the "Maximum-Signal" condition, but practically may occur at any signal voltage value.

c. Converters—The maximum plate dissipation occurs at the "Zero-Signal" condition and the frequency at which the oscillator-developed bias is a minimum. The screen dissipation for any reasonable variation in signal voltage must never exceed the rated value by more than 10%.

d. Screen Ratings—When the screen voltage is supplied through a series voltage-dropping resistor, the maximum screen voltage rating may be exceeded, provided the maximum screen dissipation rating is not exceeded at any signal condition, and the maximum screen voltage rating is not exceeded at the maximum-signal condition. Provided these conditions are fulfilled, the screen-supply voltage may be as high as, but not above, the maximum plate voltage rating.

8. TYPICAL OPERATION — For many receiving tubes, the data show typical operating conditions in particular services. These typical operating values are given to show concisely some guiding information for the use of each type. They are not to be considered as ratings, because the tube can be used under any suitable conditions within its rating limitations.

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RECEIVING TUBES

The ratings of all receiving tubes currently used in new equipment are set up according to the design-center system. Older and obsolescent types of receiving tubes still have absolute maximum ratings because these types are used only for renewal purposes and, therefore, design-center values are of no practical value. **Receiving-tube types rated on the design-center system are identified in the Receiving-Tube Section either by a large star in the index corner of each data page or by the statement "Maximum Ratings Are Design-Center Values" preceding the ratings on each data page.**

TRANSMITTING TUBES

The ratings of transmitting tubes grouped in the Transmitting-Tube Section are on the basis of the absolute system. This system enables the transmitter design engineer to choose his design values so as to obtain maximum performance within the tube ratings. Such design procedure has been considered practical for large transmitters where adequate controls are usually incorporated in the design, and ordinarily an experienced operator is present to make any necessary adjustments.

The maximum ratings given for each transmitting type on its data pages apply only when the type is operated at frequencies lower than some specified value which depends on the design of the type. As the frequency is raised above the specified value, the radio-frequency currents, dielectric losses, and heating effects increase rapidly. Most types can be operated above their specified maximum frequency provided the plate voltage and plate input are reduced in accordance with the information given in the table "Transmitting-Tube Ratings vs Operating Frequency" in the front part of the Transmitting-Tube Section.

For certain air-cooled transmitting tubes, two sets

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of absolute maximum values are shown to meet diversified design requirements. One set is designated as CCS (Continuous Commercial Service) ratings, while the other is called ICAS (Intermittent Commercial and Amateur Service) ratings.

Continuous Commercial Service is defined as that type of service in which long tube life and reliability of performance under continuous operating conditions are the prime consideration. To meet these requirements, the CCS ratings have been established.

Intermittent Commercial and Amateur Service is defined to include the many applications where the transmitter design factors of minimum size, light weight, and maximum power output are more important than long tube life. These various factors have been taken into account in establishing the ICAS ratings.

Under the ICAS classification are such applications as the use of tubes in amateur transmitters, and the use of tubes in equipment where transmissions are of an intermittent nature. The term "intermittent" is used to identify operating conditions in all applications other than amateur in which no operating or "on" period exceeds 5 minutes and every "on" period is followed by an "off" or standby period of at least the same or greater duration.

ICAS ratings are considerably higher than CCS ratings. They permit the handling of greater power, but tube life under ICAS conditions, of course, is reduced. However, the transmitter designer may very properly decide that a small tube operated with ICAS ratings better meets his requirements than a larger tube operated with CCS ratings. Although such use involves some sacrifice in tube life, the period over which tubes will continue to give satisfactory performance in intermittent service can be extremely long depending on the exact nature of the service.

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The choice of tube operating conditions best fitted for any particular application should be based on a careful consideration of all pertinent factors.

RECTIFIER TUBES

Rectifier tubes used principally in receiving equipment are rated according to the design-center system, while those used primarily in transmitting and laboratory equipment are rated according to the absolute system. The method of identifying which rating system is used for any rectifier tube in this Handbook is the same as that for other tubes in the particular section of the Handbook in which data for the rectifier tube are given.

The ratings of rectifier tubes are based on fundamental limitations in the operation of the tubes themselves, and in general include the following: maximum peak inverse plate voltage, maximum peak plate current, and maximum d-c output current.

Maximum peak inverse plate voltage is the highest instantaneous plate voltage which the tube can withstand recurrently in the direction opposite to that in which it is designed to pass current. For mercury-vapor tubes and gas-filled tubes, it is the safe top value to prevent arc-back in the tube operating within the specified temperature range.

In determining peak inverse plate voltage on a rectifier tube in a particular circuit, the equipment designer should remember that the relations between peak value of inverse plate voltage, rms value of input voltage, and average value of output voltage, depend largely on the characteristics of the particular rectifier circuit and the power supply. Furthermore, the presence of transients, such as line surges and keying surges, or waveform distortion, may raise the actual inverse plate voltage to a peak higher than that calculated for sine-wave voltages. Therefore, the actual inverse plate voltage on a rec-

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tifier tube should never exceed the maximum peak inverse plate voltage rating for that tube. The peak inverse plate voltage may be determined with an electronic peak voltmeter of the self-contained battery type.

In single-phase, full-wave rectifier circuits with sine-wave input and pure resistance load, the peak inverse plate voltage is approximately 1.4 times the rms value of the plate-to-plate voltage supply. In single-phase, half-wave circuits with sine-wave input and pure resistance load, the peak inverse plate voltage is approximately 1.4 times the rms value of the plate voltage supply, but with condenser input to filter, the peak inverse plate voltage may be as high as 2.8 times the rms value of the plate voltage supply.

Maximum peak plate current is the highest instantaneous plate current that a tube can safely carry recurrently in the direction of normal current flow. The safe value of this peak current in hot-cathode types of rectifier tubes is a function of the electron emission available and the duration of the pulsating current flow from the rectifier tube in each half-cycle.

The value of peak plate current in a given rectifier circuit is largely determined by filter constants. If a large choke is used at the filter input, the peak plate current is not much greater than the load current; but if a large condenser is used at the filter input, the peak current may be many times the load current. In order to determine accurately the peak plate current in any rectifier circuit, the designer should measure it with a peak-indicating meter or use an oscillograph.

Maximum d-c output current is the highest average plate current which can be handled continuously by a rectifier tube. Its value for any rectifier tube type is based on the permissible plate dissipation of that type. Under operating conditions involving a rapidly

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repeating duty cycle (steady load), the average plate current may be measured with a d-c meter. In the case of certain mercury-vapor tubes where the load is fluctuating, it is necessary to determine the average current over the time interval specified on the data pages for these types.

In addition to the above ratings for rectifier tubes, other ratings may be set up for a rectifier tube when the service in which the tube is to be used makes such ratings essential for satisfactory performance. Such ratings are: maximum surge plate current, and maximum heater-cathode potential.

Maximum surge plate current is the highest value of abnormal peak currents of short duration that should pass through the rectifier tube under the most adverse conditions of service. This value is intended to assist the equipment designer in a choice of circuit components such that the tube will not be subjected to disastrous currents under abnormal service conditions approximating a short circuit. This surge-current rating is not intended for use under normal operating conditions because subjecting the tube to the maximum surge current even only once may impair tube life. If the tube is subjected to repeated surge currents, its life will be seriously reduced or even terminated.

Maximum heater-cathode potential is the highest instantaneous value of voltage that a rectifier tube can safely stand between its heater and cathode. This rating is applied to certain rectifier tubes having a separate cathode terminal and used in applications where excessive potential may be introduced between heater and cathode. For convenience, this rating is usually given as a d-c value.

CATHODE-RAY TUBES

The ratings of some cathode-ray tubes are set up on the absolute system while others are set up on the design-center system. Initially, cathode-ray tubes

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were all rated according to the absolute system. With the advent of television which presented design conditions similar to those in the receiving-set field, the method of rating popular types of cathode-ray tubes was changed to the design-center system. More recently, because of procedure standardized by the RMA Cathode-Ray-Tube Committee, newer types of cathode-ray tubes are being rated on the absolute system. Cathode-ray types rated according to the design-center system are identified in the Cathode-Ray Types Section by a statement to that effect just ahead of the maximum ratings on each data page. The data pages of types rated according to the absolute system have either (1) no identifying statement as to the rating system, or (2) an identifying statement that the ratings are according to the absolute system.

PHOTOTUBES

The ratings of all phototubes in the Phototube Section are on the absolute maximum basis. This basis enables the designing engineer to choose design values so as to obtain optimum performance within tube ratings. In the case of gas phototubes, the value to which the plate voltage and the plate current can be raised is abruptly limited by ionization effects. If these are allowed to occur, they may ruin the photosurface almost instantly. While phototubes in general might be rated on the design-center basis, such a procedure, with provision for an adequate factor of safety to take care of all conditions of operation, would impose undue limitations on the use of gas phototubes.

MISCELLANEOUS SPECIAL TUBES

The ratings of some of the various tube types grouped in the Miscellaneous-Types Section are according to the design-center system while others are according to the absolute system. Miscellaneous types rated on the design-center basis are identified

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by a statement to that effect on the data pages or else refer back for ratings to a receiving-tube type whose rating basis is explained under TUBE RATINGS—Receiving Tubes. The data pages of types rated according to the absolute system have either (1) no identifying statement as to the rating system, or (2) an identifying statement that the ratings are according to the absolute system.

CHARACTERISTICS and TYPICAL OPERATING CONDITIONS

In addition to showing the ratings of each tube type, the data pages for many of the types in this Handbook include "characteristics," such as amplification factor, plate resistance, and transconductance, which help to distinguish between the electrical features of the respective types. Usually, the characteristics shown for any type are obtained for that type in class A service: where class A data are given for the type, the characteristics are included with that data for convenience. Based on a large number of tubes of a given type, the values shown for these characteristics are average values.

Range of Characteristics—The equipment designer should bear in mind that individual tubes of a given type may have characteristics values either side of the average values shown for the type. He should also realize that these characteristics change during the life of individual tubes. In designing equipment, therefore, he should allow for the maximum cumulative variation of any characteristic from the average value of that characteristic as shown in the tabulated data for the type. The exact percentage of the variation will be different for different types of tubes depending on the design of the tubes and their intended application, but in general the designer should consider a probable plus or minus variation of not less than 30 per cent.

Furthermore, the equipment designer should recog-

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nize the desirability of designing equipment so that the full range of the operating characteristics of tubes will be utilized. If this practice is not followed, he imposes on the equipment user special replacement problems in that the user will have to select tubes suitable for use in the equipment, and may not be able to obtain the full life capability of such tubes.

Typical Operating Values—Also included on the data pages is information on typical operating conditions for most of the various tubes when used in particular services. These typical operating values are intended to show concisely some guiding information for the use of each type. They must not be considered as ratings because each type can, in general, be used under any suitable conditions within its rating limitations. In referring to these values for transmitting tubes, it should be noted that the power output value is not a rating. It is an approximate tube output, i.e., tube input minus plate loss. Circuit losses must be subtracted from tube output in determining useful output.

Datum Point for Electrode Potentials—In the data for any type in the Handbook, the values for grid bias and positive-potential-electrode voltages are given with reference to a specified datum point as follows. For types having filaments heated with d.c., the negative filament terminal is taken as the datum point to which other electrode voltages are referred. For types having filaments heated with a.c., the mid-point (i.e., the center tap on the filament-transformer secondary, or the mid-point on a resistor shunting the filament) is taken as the datum point. For types having equipotential cathodes indirectly heated, the cathode is taken as the datum point.

Grid Bias vs Filament Excitation—If the filament of any type for which data are given on a d-c basis is to be operated with an a-c supply, the given grid

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bias should be increased by an amount approximately equal to one half the rated filament voltage and be referred to the filament mid-point. Conversely, if it is required to use d-c filament excitation on any filament type for which the data are given on an a-c basis, the grid-bias values as given on the data pages should be decreased by an amount approximately equal to one half the rated filament voltage and be referred to the negative filament terminal instead of the mid-point as in a-c operation.

In practice, the necessity for following this rule depends on circuit conditions and operating requirements. If the bias is relatively small compared with the filament voltage and hum is a consideration, adjustment of the grid bias is ordinarily essential. Conversely, if the bias is relatively large compared with the filament voltage, adjustment of the grid bias may be unnecessary.

When filament excitation of tubes used as Audio Amplifiers is changed from d.c to a.c., the grid return should, in general, be shifted to the mid-point of the filament circuit to minimize hum, and the bias adjusted accordingly. When the excitation is changed from a.c. to d.c., bias adjustment depending on the relative values of bias and filament voltage may be required to provide the full signal-handling capability of the tubes.

When filament excitation of tubes used as R-F Amplifiers is changed, bias adjustment is not required unless the change makes the circuit critical as to hum or signal-handling capability. For example, in class C amplifiers, the bias is usually so large in comparison with the filament voltage that adjustment is generally unnecessary.

Grid Current and Driving Power—The typical values of d-c grid current and driving power shown for triodes and tetrodes in class B r-*f* service and in class C service are subject to variations depending on the impedance of the load circuit. High-impe-

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dance load circuits require more grid current and driving power to obtain the desired output. Low-impedance circuits need less grid current and driving power, but plate-circuit efficiency is sacrificed. In comparison, the d-c grid current and driving power shown for beam tubes and pentodes in class B r-f service and in class C service are not as critical to variations in load-circuit conditions. In any event, sufficient grid current should be used so that the stage is "saturated," i.e., so that a small change in grid current results in negligible change in power output. Regardless of the type of tube used, the driving stage should have a tank circuit of good regulation and should be capable of delivering power in excess of the indicated power by a factor of several times.