The characteristics and curves published in this Handbook are based upon the average of readings taken on a number of valves, and the performance figures given under "Typical Operating Data" are values to be expected when average valves are used under appropriate conditions. The conditions selected are those under which the power delivered and the efficiency are as high as possible compatible with good valve life.

## Amplification Factor

The amplification factors quoted for pentodes and tetrodes are those of $g_1$ with respect to $g_2$.

## Drive Power

The value given is the power actually absorbed at the grid of the driven valve. The previous stage should be capable of delivering from twice to three times this power to allow for circuit losses.

## Input Voltage

The value quoted is the peak value ($v_{pk}$) unless otherwise stated. For push-pull stages the grid-to-grid value is given.

## Output Power

The value given is the total output delivered by the valve. The useful power will be somewhat less, dependent upon circuit losses.

## Mercury Vapour Rectifiers

The maximum peak inverse voltage figure applies up to a maximum supply frequency of 150 c/s. At 500 c/s this value must be reduced by 15% and at 800 c/s by 25%.

By "D.C. Output Voltage" is meant the mean value of the unsmoothed rectified voltage, i.e., the voltage input to the filter.

*The following recommendations should be interpreted in conjunction with British Standard Code of Practice No. CP1005: Part 7: 1954, 'The Use of Electronic Valves', upon which these notes have, in part, been based.*

## GENERAL

The published characteristics and curves are based upon the average of readings taken on a number of valves and the operating conditions given are those which result in optimum power output and efficiency without over-running the valve. Failure to observe the various recommendations may seriously reduce the life of the valve and in some instances result in catastrophic failure.

## LIMITING VALUES

The limiting values are absolute. It is important that none of these limits are ever exceeded and such variations as mains fluctuations, component tolerances and switching surges, must be taken into account in deciding the nominal valve operating conditions.

In some instances, such as pulse operation or intermittent service, it may be permitted to exceed the absolute values but, to ensure the validity of the guarantee, the desired operating conditions must be agreed with Mullard Limited, (Industrial Technical Service Department).

## TYPICAL OPERATING CONDITIONS

Typical operating conditions are shown for various modes of operation, e.g. 'r.f. power amplifier class C telegraphy' or 'telephony', etc. Some of the typical operating conditions for a particular mode of operation may incorporate one or more of the absolute ratings; in such cases the designer should take precautionary steps to ensure that these ratings are never exceeded.

## FILAMENT OR HEATER SUPPLY

Either a.c. or d.c. supply may be used for filament heating. The published negative grid bias voltages are based upon a.c. heating. When d.c. heating is employed for directly heated valves the grid bias should be reduced by one-half of the filament voltage and when the anode current is greater than 5% of the filament current the h.t. return should be taken to a centre point resistor or to a reversing switch. When a.c. is employed the h.t. return should be taken to the centre tap of the filament transformer.

Measurements of the filament or heater voltage should always be made after the valve and supply transformer have attained their working temperature, and should be taken at the valve pins or terminals.

(*a*) *Oxide-coated Filaments and Cathodes*

To obtain maximum life the filament or heater voltage must be within ±2.5% of the nominal value and temporary fluctuations should not exceed ±10%.

With valves specially designed for use in mobile transmitters, emergency operation of the filament or heater down to the specified voltage is allowed.

(*b*) *Thoriated Tungsten Filaments*

To obtain maximum life the filament voltage must be within ±1% of the nominal value and temporary fluctuations should not exceed ±5%.

(*c*) *Pure Tungsten Filaments*

It is essential, when using valves with pure tungsten filaments, that the recommended filament operating conditions are never exceeded. The filament voltage marked on such valves is that which provides the rated total emission (i.e. 90% of the saturation emission) when the valve is new. In order to maintain this emission over the whole life of the valve, the filament voltage must be increased progressively to a total maximum of 105%. When less than the rated total emission is required for a particular application, the life can be extended by operating the filament at a reduced voltage.

(*d*) *Filament Switching*

It may be necessary with some valves to limit the filament current when switching on the supply. Information on this will generally be included on individual data sheets but in cases of doubt Mullard Limited, (Industrial Technical Service Department) should be consulted.

## COOLING

(*a*) *General*

With radiation-cooled valves the maximum base, seal and envelope temperatures are given in the published data. To avoid exceeding these it may sometimes be necessary to provide artificial cooling.

In the development stage of an equipment the various temperatures should be measured with due regard to the ultimate environmental conditions. Special paints and lacquers are available for this purpose but any other suitable method can be used.

In some cases the filament and grid seals of water-cooled, forced-air-cooled and silica valves require cooling and guidance is given on individual data sheets.

Where additional cooling is necessary for safe operation precautionary steps must be taken to switch off all supply voltages in the event of failure or reduction of the cooling medium.

(*b*) *Water-Cooling*

A water-cooled valve should always be used with the recommended type of water jacket. The circulating cooling water should be as free as possible from all solid matter and the dissolved oxygen content should be low. Whenever possible a closed water system using distilled or demineralised water should be employed. In general, the resistivity of the cooling water should not be less than 3.3k$\Omega$/c.c and the inorganic solid content should not exceed 3 parts in $10^5$, but for some applications and some types of valves it may be desirable for the resistivity to be considerably higher and the solid content to be less. If desired, Mullard Limited, (Industrial Technical Service Department) will undertake to analyse the available water supply.

The temperature limits given in the individual data sheets should in no circumstances be exceeded and it is essential to insert an automatic device in the water outlet to switch off the supply voltages in the event of the failure or reduction of the water supply.

(*c*) *Forced-Air Cooling*

The temperature limits laid down in the data sheets should in no circumstance be exceeded and precautions should be taken to switch off all supply voltages in the event of a fault in the air circulating system.

The use of an inlet filter in the air supply is recommended particularly in dusty or dirty locations to avoid clogging the radiator air ducts.

(*d*) *Auxiliary Air and Water-Cooling*

Where auxiliary cooling is specified, e.g. for grid seals, precautionary steps must be taken to switch off all supply voltages in the event of the failure or reduction of these auxiliaries.

## VALVES IN R.F. HEATING APPLICATIONS

The service conditions associated with r.f. heating, i.e. induction heating, dielectric-loss heating and short wave diathermy, can be more severe than those associated with communication service.

These severe conditions are mainly due to the wide variations in load impedance usually encountered which, in turn, produce large variations in grid current, anode current, grid dissipation and anode dissipation. The risk of exceeding the valve ratings is, therefore, increased.

For valves recommended for r.f. heating applications, the data sheets include ratings and typical operating conditions calculated to provide margins of safety against variations of load and supply voltage. Since it is not possible to anticipate the degree of protection which a designer may wish to incorporate, these data generally give two sets of operating conditions:

(*a*) for the valve fed from an unsmoothed d.c. supply and where no protection is incorporated in the equipment against valve overload, under-drive or inefficient operation, and:

(*b*) for the valve fully protected; this offers a performance only slightly less than that allowed for maximum 'class C telegraphy.'

The designer may choose an operating condition between these extremes depending upon the degree of protection which he decides to incorporate in the equipment. However, no limiting values may be exceeded during the work cycle.

It may sometimes be desired to use a valve for which no industrial ratings are given. The following table considers five methods of operation of triodes and indicates the factors by which the maximum 'class C telegraphy' should be multiplied in order to arrive at a safe rating, and designers are strongly recommended to give due consideration to these factors:

*Method* 1. Equipments fitted with effective automatic mains voltage stabilisation and effective automatic protection against valve over-load and over-drive and in which the power supply is derived from a filtered source containing not more than 5% ripple. (Three-phase full-wave and six-phase half or full-wave rectifier systems whether filtered or unfiltered, may be taken as meeting this requirement.)

*Method* 2. D.C. smoothed but unprotected.

*Method* 3. Equipment supplied by unsmoothed full-wave biphase rectifier but not fitted with automatic regulation or overload protection.

*Method* 4. Self-rectifying equipment half-wave operation.

*Method* 5. Self-rectifying equipment full-wave operation without smoothing choke.

FACTORS APPLICABLE TO EACH VALVE

| *Method* | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Anode voltage r.m.s. | — | — | — | 0.8 | 0.8 |
| Anode voltage d.c. | 0.95 | 0.8 | 0.7 | — | — |
| Anode current | 0.95 | 0.8 | 0.7 | 0.4 | 0.4 |
| Power input | 0.9 | 0.65 | 0.6 | 0.3 | 0.3 |
| Anode dissipation | 0.95 | 0.6 | 0.6 | 0.6 | 0.6 |
| Control-grid current | 0.9 | 0.8 | 0.7 | 0.4 | 0.4 |
| Control-grid dissipation | 0.9 | 0.7 | 0.7 | 0.7 | 0.7 |

Should it be desired to use tetrodes for r.f. heating applications Mullard Limited, (Industrial Technical Service Department) should be consulted.

To avoid damage to the valve in the event of an overload it is recommended that the minimum protection incorporated in industrial heating equipment should include a rapid action device to cut off the h.t. when the anode or grid current exceeds the maximum rating. If the anode dissipation at zero grid bias exceeds the limiting value, then grid under-current protection is also recommended in case oscillation ceases while the h.t. is applied. Further, where water or forced-air cooling of the valve is used, protection against failure of the cooling system is necessary.

## MOUNTING

It is strongly recommended that all valves be mounted vertically. It is, however, permissible to mount some of the smaller valves horizontally provided that, for directly heated valves, the plane of the filament is vertical or, for indirectly heated valves, the plane of the major axis of the first grid is vertical. Recommendations on mounting are given on the data sheets when necessary.

Leads having sufficient flexibility to allow for thermal expansion and other movements should be employed for the external connections to those valves whose construction is such that stress might otherwise be set up in the seals.

When designing a mounting for an r.f. valve, it is important to avoid closed circuits of conducting material in regions of strong r.f. fields, otherwise considerable loss of output may result. It is always preferable to keep the quantity of any material in the r.f. field to a minimum.

Where a valve with an internal anode (e.g. silica valve TYS5-3000) is mounted in a clamp, any large metal parts of the clamp which are located in the region of the anode should be connected to anode terminal. This will prevent heating of the glass or silica which would otherwise result from the r.f. potential gradient between the anode and the clamp.

Clamps used for supporting silica valves should be designed in such a way as to accommodate the usual envelope tolerances and thus avoid undue pressure being applied to the envelope.

## DRIVE POWER

The value of grid current stated on the data sheets is intended only as a guide, and in making adjustments to the circuit the important factor to note is the grid driving voltage. Either over-driving or under-driving will result in a reduction in efficiency.

At low radio frequencies the drive power required for 'class C' operation can be calculated from the expression

$$P_{drive} = 0.9 \times v_{in\,(pk)} \times I_{g1}\ (d.c.)$$

at higher frequencies more drive power is required due to input damping. The value given for the symbol $P_{load(driver)}$ is the power which must be available from the driver stage to provide for valve drive, input damping and circuit losses. It may be necessary to allow more for a circuit designed for a wide tuning range.

## POWER OUTPUT

The valve output figures ($P_{out}$), represent the power which the valve will deliver to the circuit and load; a figure of load power ($P_{load}$) allowing for a typical circuit transfer efficiency for the type of service under consideration is stated.

When it is desired to operate power valves at frequencies so high that the efficiency is falling the input must be reduced.

## REDUCED OPERATING LEVELS

(*a*) When it is desired to operate valves at reduced power levels at h.f. the valve conversion efficiency can be kept at the maximum by decreasing the input current rather than the voltage.

(*b*) When operating above about 100Mc/s however, circuit losses are higher and it is preferable to keep the input current high and reduce the voltage, thus minimising the circuit loss and obtaining a better load power.

(*c*) When the frequency of operation is so high that the efficiency is decreased the input power must be reduced in order to avoid excessive electrode dissipations. This should be achieved by reducing the anode voltage, see frequency/voltage characteristic in the individual data sheets.

## POWER DISSIPATED IN VALVE ELECTRODES

Dissipation in the screen-grid is given by the product of d.c. voltage and current

$$p_{g2} = V_{g2} \times I_{g2}$$

Power in the control-grid for 'class C' operation at low radio frequencies can be closely approximated from the peak positive value of drive voltage and the d.c. grid current. (The peak positive voltage is the drive voltage less the magnitude of the bias voltage.)

$$p_{g1} = I_{g1} \left[0.9\, v_{in(pk)} - |V_{g1}|\right]$$

At higher radio frequencies the grid dissipation will be somewhat higher due to the increased capacitive current in the electrode.

In many radiation-cooled types the anode becomes visibly hot when near full dissipation and the temperature can be measured by a pyrometer. The temperature for full rated dissipation is usually given in the data sheets but any other loading may be checked by making comparative measurements with d.c. power, under non-oscillatory conditions.

For valves whose anodes are cooled by circulated water or by forced-air, the anode dissipation can be assessed by measuring the rise of temperature and flow of the cooling medium.

Radiation-cooled valves which do not colour may be assessed by covering with an insulating hood, vented to produce a reasonable equilibrium temperature and provided with some form of thermometer. The measured temperature under normal operating conditions may then be checked by making comparative measurements with d.c. power, under non-oscillatory conditions.

## CLASS 'B' LOW FREQUENCY APPLICATIONS

The performance shown on the data sheets is based on an ideal circuit with no transformer losses, a resistive load, constant supply voltages and a sinusoidal input voltage. Allowances should be made for these factors in assessing the actual useful output power.

To reduce distortion due to the flow of grid current the impedance of the circuit supplying the input to the valve must be low. The use of a cathode follower driver stage is recommended, but an input transformer with a low output impedance or with a low damping resistance may be used.

The type of driver valve chosen must be able to deliver sufficient power to overcome the circuit losses in addition to providing the actual valve drive power.

## STORAGE AND INSTALLATION

(*a*) *Mounting*

All large valves should be mounted with the filament vertical. The recommendation contained in individual data sheets as to the accuracy of the mounting should be complied with, otherwise the filament may sag towards the grid under its own weight.

In mobile or portable equipment, and in fixed installations subject to vibration, care should be exercised to ensure that the valve supports or chassis are suitably designed to protect the valve from mechanical shock and vibration.

(*b*) *Corona Effects*

Metal parts (particularly sharp points or edges), which might cause intense electrostatic fields, should not be located in the vicinity of valves operating at high voltages, since corona discharge may occur and cause damage to the valve. On installation, filament and other flexible leads should be kept well clear of the bulb and adjacent conductors.

(*c*) *Storage and Transit*

Valves not installed in equipment should be stored in their original packing or in racks. Any rack employed should be designed to protect the valve from excessive shaking or vibration and be so constructed that no stresses are imposed on the seals or the envelope.

Normal good storage conditions should be provided to prevent deterioration, such as corrosion of contacts or impairment of electrical insulation.

Valves should always be transported in the original packing designed for the purpose.

## CONDITIONING

After transit or a period of storage it is recommended that power valves should be operated for not less than 15 minutes with the filaments only energised before being put into full service. In addition, with valves having anode voltages in excess of 5kV, the anode voltage and input power should be increased gradually or in several steps for a further period of 15 minutes, or longer, until normal operation is achieved. This treatment will clean-up traces of gases which may be present and which could cause premature failure of the valve.

Where valves are being held in store for an indefinite period it is recommended that periodic conditioning and testing is carried out as a safeguard against deterioration of vacuum. The interval of testing will, of course, depend upon the size and type of valve, and users are invited to contact Mullard Limited, (Industrial Technical Service Department) for details of treatment of individual valves.

## PRESENTATION OF VALVE DATA

The symbols component and base references incorporated in the data are in accordance with the following British Standards:—

| | |
|---|---|
| 1409: 1950 | Letter symbols for electronic valves. |
| 1991: Part I: 1954 | Letter symbols, signs and abbreviations. |
| 530: 1948 (with supplements) | Graphical symbols for telecommunications. |
| 448: 1953 | Electronic valve bases, caps and holders. |