

The use of electronic valves

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THE USE OF ELECTRONIC VALVES

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Foreword

The earlier edition of CP 1005, was published in four parts. Parts 1 and 2 were published together in 1954, Part 3 in 1956 and Part 4 in 1958.

In amending and extending the material in the Code, the opportunity has been taken to combine the four parts in one document.

To facilitate the separation of explanatory material from the recommendations in the Code, the explanatory material is printed in a type smaller than that used for recommendations and is inset.

This Code of Practice represents a standard of good practice and therefore takes the form of recommendations. compliance with it does not confer immunity from relevant legal requirements, including bye-laws.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 46 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. Introduction

101 Scope

This Code of Practice is intended to give guidance to designers of equipment using electronic valves, so that optimum performance and life may be secured.

Section 2 gives recommendations applicable to all electronic valves, and subsequent sections give additional recommendations specifically appropriate to different classes of valves.

It is proposed to revise and extend the Code from time to time to keep it abreast of developments.

The recommendations contained in this Code relate to all applications of valves but it should be appreciated that where a higher degree of reliability is required, such as in certain industrial or communications equipment, additional or more stringent precautions may be necessary.

This Code of Practice is not intended to cover recommendations for the safety of personnel but the particular attention of designers is drawn to any information regarding ionising radiation which the manufacturer may publish in connection with the devices covered by this Code of Practice, because of the possible necessity of shielding in equipment.

Reference should also be made to BS 415, "*Safety requirements for radio or other electronic apparatus for acoustical or visual reproduction (electric-mains-supplied)*" to CP 321.102, "*Installation and maintenance of electrical machines, transformers, rectifiers, capacitors and associated equipment*" and BS 3192, "*Safety requirements for radio (including television) transmitting apparatus*".

When electronic tubes and valves are operated at voltages in excess of 5 kV, the advice of the manufacturer should be sought as to whether or not X-radiation is likely to occur under the particular conditions of use envisaged and, if so, the level of such radiation.

The advice of the Radiological Protection Service (Ministry of Health and Medical Research Council) should then be sought as to whether that level of radiation is likely to constitute a hazard to users under specified conditions.

The recommendations in this Code of Practice are based on original material provided by the British Radio Valve Manufacturers' Association.

102 Definitions

For the purpose of this Code the following definitions apply in addition to those given in BS 204, "*Glossary of terms used in telecommunication (including radio) and electronics*".

102.1

electronic valve

valve, vacuum tube, or photocell as defined in BS 204. The term also includes the devices dealt with in the separate sections of this Code

NOTE The term "valve" is used for convenience throughout the Code and is to be read as meaning "electronic valve".

102.2

gas-filled valve

a valve with gas and/or vapour fillings

102.3

electron device

an electronic valve or tube, transistor or other semi-conductor unit

NOTE This definition excludes inductors, capacitors, resistors and similar components.

102.4

bogey electron device

an electron device whose characteristics have the published nominal values for the type. A bogey electron device for any particular application can be obtained by considering only those characteristics which are directly related to the application

102.5

rating

a value which establishes either a limiting capability or a limiting condition for an electron device. It is determined for specified conditions of environment and operation and may be stated in any suitable terms

NOTE Limiting conditions may be either minima or maxima.

102.6

rating system

the set of principles upon which ratings are established and which determine their interpretation

NOTE The rating system indicates the division of responsibility between the device manufacturer and the circuit designer with the object of ensuring that the working conditions do not exceed the ratings.

102.7

electrode potential

when an electrode potential (or voltage) is specified it is understood as being with reference to the cathode or negative filament connection unless otherwise stated

102.8

commutation factor

the product of the rate of current decay in amperes per microsecond just prior to current zero and the rate of inverse voltage rise in volts per microsecond just after current zero

Section 2. Recommendations for all electronic valves

201 General

The recommendations made in this section apply in general to all electronic valves. Where exceptions exist, reference to them will be made in the special sections concerned. The latter should therefore be read in conjunction with this section.

a) *Published data.* The published data on specific valve types should always be studied before the design of equipment is undertaken. Where exceptional needs arise, or where a valve is to be put to a use which does not appear to be provided for by the published data, the valve manufacturer should be consulted so that the equipment designer may have the advantage of any additional information from kindred applications and from life tests. In addition, any equipment designer who develops a new application for a valve should consult the valve manufacturer to ensure that the new needs may be provided for by suitable tests and so that the manufacturer can be kept abreast of current requirements.

When major departures from current practice are contemplated: the valve manufacturer should be informed well in advance, so that, if necessary, new ratings can be established from a series of preliminary trials and confirmed by further tests on a variety of production batches of valves. Unless the valve manufacturer is so informed, he will be faced with the choice of suggesting either a rating which may be needlessly conservative or one involving unknown risks.

b) *Selection of electronic valves.* It is not practicable for valves to be specially selected for individual equipments. In view of the obvious difficulty of estimating the effect of the use of valves having one or more characteristic at a limiting value, it is very desirable that initial tests should be made with the largest reasonable number of equipments and valves.

c) *Early samples.* When equipment is being designed on the basis of new valve types it should be borne in mind that there may be considerable variations in characteristics and dimensions between first samples and subsequent production.

Early samples of new valves often embody a considerable amount of handwork and are not necessarily typical of the mass-produced article. For example, owing to the skill of individual craftsman, hand-made samples may be superior in some respects to the production valves. On the other hand, the product of a smoothly running factory will in general be more consistent than that of the laboratory. Any design work based upon first samples should, therefore, be undertaken in consultation with the valve manufacturer. Circuit design based on the mean characteristics of a limited number of early sample valves is liable to serious error and should not be adopted for production.

202 Dimensions

When the use of established types is being contemplated in the design of new equipment, particular attention should be paid to the published dimensions. It is important that reliance should not be placed upon dimensions taken from individual valves. This is to ensure that adequate space is allowed and that valve shields, retaining and mounting devices can accommodate all valves of the type.

203 Ratings

a) *General.* Ratings cannot be considered as barriers on one side of which satisfactory operation is obtained while on the other side immediate failure will occur. The expectation of life generally decreases continuously as the ratings are approached, for example with respect to envelope or seal temperature. Exceeding the rating accelerates this decline. With a few exceptions the more conservative the use of the valve with respect to ratings the greater is the life expectancy and reliability.

The first maximum or minimum rating reached should be the limiting factor. All ratings are not mutually compensating, for example it is not safe to assume that one rating (e.g. maximum anode voltage) may be exceeded provided a corresponding reduction is made to some other rating (e.g. the anode current) although this may be permissible in some instances. Changes of ratings which are announced with a particular valve type are not necessarily applicable to types which appear otherwise similar. The rating of a valve is usually given in terms of one or more of the following systems.

b) *Ratings systems.*

i) *Absolute maximum rating system.* A system of limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data, which 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 the effect of equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturers 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 condition of supply voltage variation, equipment component variation, equipment control adjustment, load variations, signal variation, environmental conditions, and variations in characteristics of the device under consideration and of all other electron devices in the equipment.

ii) *Design centre rating system.* A system of limiting values of operating and environmental conditions applicable to a bogey electron device of a specified type as defined by its published data, which should not be exceeded under normal conditions.

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

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

iii) *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 the characteristics of the device under consideration.

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 conditions of supply-voltage variations, equipment component variation, variations in characteristics of all other devices in the equipment, equipment control adjustment, load variation, signal variation and environmental conditions.

c) *Atmospheric pressure limitations.* Except where otherwise stated, ratings apply to operation at normal atmospheric pressure at altitudes below 1 000 metres. In the event of valves being operated at other pressures the valve manufacturers should be consulted unless specific ratings are given for the intended use.

This provision refers for example to the use of valves in aircraft, when the reduced atmospheric pressure at high altitudes may greatly increase the risk of external voltage flashover, and may also greatly reduce the effect of convection cooling. Since many valves and other components are rated under free air conditions, excessively high temperatures may be developed due to the lack of convection cooling. Particular attention should be paid to the hot-spot envelope temperature of valves since, not only will the life of the valves be seriously reduced but the characteristics may change appreciably with the high temperature. It is essential that the performance checking of equipment should be done under conditions as representative as possible of the normal operating conditions of pressure unless adequate measures have been taken to keep temperatures within the rating e.g. pressurization or conduction cooling or combination of both. Defects which occur at an ambient temperature of 100 °C may not necessarily be repeated in an ambient temperature of 20 °C. Conduction cooling systems applied directly to the valve envelopes are strongly recommended.

d) *Frequency limitations.* When a frequency range is specified, the valve ratings apply only within this limitation. In some instances valves may be operated at reduced ratings at frequencies outside those specified for the maximum ratings. Unless, however, such reduced ratings are specified they should not be assumed without consultation with the valve manufacturer.

If some types of valves are used appreciably above their maximum frequency rating, the power dissipated in the lead-in wires owing to resistance losses, and in the glass between the leads owing to dielectric losses, may be sufficient to overheat the wires or the glass. Further, there is an increased danger of damage to the valve owing to eddy current losses heating the envelope. Such effects may release gas into the valve or cause the glass to soften or crack.

In the case of high-vacuum rectifiers designed for use at mains frequency, increasing the operating frequency may cause electrolysis of the glass, particularly in those types in which the anode is supported by metal wings touching the envelope. Early failure may also occur owing to the filament resonating at the operating frequency, and either short-circuiting to the anode or breaking due to fatigue.

It is most important, therefore, that rectifiers intended for operation at 50 c/s should not be used appreciably above this frequency without the manufacturer's approval.

e) *Pulse operation limitations.* Where no pulse or peak ratings are specified it must not be assumed that the valves will function satisfactorily if the average values under pulse operation conditions are within the normal rated values.

Under pulse conditions the average values of, for example, current and voltage may be well within the normal ratings but very high values will be required for short periods of time and unless the valve has been manufactured to meet these requirements premature failure may occur.

204 Heater or filament voltage regulation and supplies

a) *General.* A valve is designed to have optimum life and performance at its rated voltage or current and to withstand limited deviations from these values. Certain types of valve such as large rectifiers and those having tungsten or thoriated-tungsten filaments, require a very close control of heater or filament voltage and the permissible variations should be specifically ascertained and observed. With oxide-coated and to some extent with thoriated-tungsten cathodes, low heater or filament voltages are as much to be avoided as high filament voltages and the equipment should be so designed and adjusted that the average heater or filament voltage has the nominal rated value. This precaution is particularly necessary for gas-filled and vapour-filled valves.

When measuring heater or filament voltages, the voltmeter should be connected to the valve pins or terminals. This is of particular importance with large valves in which the filament current is often considerable and appreciable error, arising from the voltage drop in the filament supply leads, may result if the filament voltage is measured at, for example, the supply source. In addition, where the waveform of the heater/filament supply is not sinusoidal, care should be taken to use suitable measuring instruments (meters embodying rectifiers are generally not suitable for this purpose).

Heater or filament voltage regulation under systems other than the absolute maximum require different interpretations according to the type of power supply used and are covered in sub-clauses b) to g) inclusive below.

b) *Parallel operation from mains.* Valves supplied in parallel from a transformer will give satisfactory operation if the voltages on the heaters and filaments are within ± 5 per cent of the rated value when the mains supply voltage is at its declared value. In the case of equipment designed for mains supplies between 200 and 250 volts this will require a minimum of three suitably spaced tapplings on the primary of the transformer.

Under these conditions the ratings allow for mains voltage variations not exceeding ± 10 per cent. Mains variations outside these limits are likely to result in some impairment of life or performance.

c) *Series operation from mains.* It is undesirable to operate valve-heaters in series except in the case of valves designed for constant current operation.

Where valve heaters are connected in series with a controlling resistance, operation will be satisfactory if the heater current is within $2\frac{1}{2}$ per cent of the rated value when the declared supply voltage is applied and valves having nominal heater voltage drop are inserted. In the case of equipment designed for mains supplies between 200 and 250 volts this requirement necessitates a minimum of three suitably spaced tapings on the controlling resistance.

Under these conditions the ratings allow for mains voltage variations not exceeding ± 10 per cent. Mains variations outside these limits are likely to result in some impairment of life or performance.

The use of certain combinations of certain types of valve heaters, owing to differing initial heating characteristics, may result in particular heaters being run at an excessive temperature during the initial warming-up period. To prevent this occurring, types which may be liable to damage will have a maximum surge-voltage rating and may require a surge-limiting device to ensure that this voltage is not exceeded.

When valve heaters or filaments are connected in series from a substantially constant voltage source, or in parallel from a substantially constant current source, or in series-parallel, the sharing of voltage or current will be determined by their resistances, which are dependent on their temperatures. These methods of interconnection cannot safely be used with combinations of directly and indirectly heated valves. When valves of different heater or filament construction are operated in such circuits it is not sufficient to ensure that the heater or filament voltages or currents are correct in normal equilibrium operating conditions.

Owing to their different temperature-resistance characteristics, it is possible that heaters or filaments may sustain abnormal temperatures during the period between switching on and the establishment of equilibrium, and also when changes occur in the supply voltages.

In a.c./d.c. equipment it is not good practice for the series resistance employed in the mains supply to be common to both h.t. and l.t. supplies for the following reasons:

- i) Automatic gain control (a.g.c.) will vary the total value of h.t. current, and this current passing through the common resistance will affect the valve heater voltage, thus causing greater variations than would be experienced owing to mains variation only.
- ii) Variations in h.t. load current due to tolerances on valves and components will cause an additional variation in heater current.
- iii) the total r.m.s. current taken by the equipment with a.c. operation will be greater than the total d.c. current with d.c. operation. A set correctly adjusted for the latter would therefore underrun the heaters on an a.c. supply.

d) *Parallel operation from lead-acid or nickel-iron cells.* Valves designed and recommended for use with chargers are intended to give satisfactory performance over the range of battery supply voltage expected with and without a charger (see also Clause 302).

- i) *Lead acid cells.* The overall variation is from 1.8 to 2.5 V per cell although it is appreciated that infrequent short-term fluctuations may raise the voltage to 2.7 V.
- ii) *Nickel-iron cells.* The mean voltage per cell should be taken as 1.25 V without charger and 1.4 V per cell with charger.

e) *Operation from 19-volt regulated supplies.* In this application a battery is connected across a generator: the battery voltage varying between $22\frac{1}{2}$ V and 29 V. In the absence of a range of valves suitable for such supplies, it will be satisfactory to employ not more than 3 valves with 6.3 V heaters, connected in series. The battery may be connected via a regulator which, throughout the ambient temperature range, provides a voltage which, measured across the 3 valve heaters in series, should be $19\text{ V} \pm 1\text{ V}$.

The types of valve run in the manner described above should be agreed with the manufacturer to avoid using valves whose heaters have widely different thermal characteristics.

f) *Other sources of supply.* Where supplies for valves are derived from sources other than those considered in the above sub-clauses, the controls should ensure that the filament/heater voltages are within $\pm 7\frac{1}{2}$ per cent of the rated values.

g) *Heater or filaments operated from pulsed or a.c. supplies at frequencies above 60 c/s.*

i) *Frequencies within a.f. range.* It should not be assumed that heaters or filaments are designed for operation above 60 c/s; their suitability for such use should be confirmed with the valve manufacturers. When the valves are suitable and are operated in the a.f. range, meters calibrated for the frequency employed should be used for measuring voltages or currents.

In certain valves the structure may have been designed to avoid mechanical resonances at normal supply frequencies, and operation above this range may result in resonances occurring which could lead to failure of the valve by mechanical damage.

ii) *R.F. or pulse operation.* For certain purposes it is necessary to supply the heaters or filaments of valves from a power supply generated by an r.f. oscillator or from a pulse source. In such circuits it is often impracticable to keep within the tolerances mentioned previously and valve manufacturers, having allowed for this in their valve design, specify wider tolerances for this application when necessary. Commonly the valve is a high voltage rectifier and it is therefore impracticable to measure the voltage by a normal voltmeter, or even by a valve voltmeter, to check that the supply is correct.

In some cases the current may be checked directly with a thermal ammeter suitably insulated and calibrated for the frequency in use, but it is often more convenient to utilize a visual comparison of filament temperature. In this method a selected average valve is set up in close proximity to the one in the equipment, but its filament or heater is operated from d.c. or 50 c/s a.c. supply.

The voltage applied to the second valve is varied until careful observation of the colours of the cathodes indicates that their temperatures are equal; this voltage is taken as the operating figure. The measurement may be assisted by the employment of a suitable optical pyrometer and it is recommended that the valves be interchanged and a second measurement made, the mean being taken as the true figure.

h) *Abnormal voltage variations.* Should the heater or filament voltage be liable to variations greater than those indicated as permissible, and if this condition cannot be overcome, in most cases it will be necessary for reduced ratings to apply to the valve. Information on any necessary rating changes should be obtained from the valve manufacturers.

Consistent emission from the cathode depends upon equilibrium between the evaporation of active material from the surface and its replacement from within. If the cathode temperature is excessive, evaporation will occur at a faster rate than replacement. If the cathode temperature is too low both evaporation and replacement will decrease and the cathode emission will be more liable to poisoning by residual gas. In either case the emission from the cathode will decline at an excessive rate and the life will be impaired.

The permissible variation of heater or filament voltage (and therefore of cathode temperature) does not depend upon one valve alone but is governed to some degree by the nature of the circuit and of the other associated valves.

Active material evaporated by excessive cathode temperature may be deposited on other electrodes; if deposited on the grid it may cause grid emission thus seriously damping the input-circuit. For example, a high mutual conductance triode which may seem quite normal on static tests may, owing to grid emission, give a poor performance under operating conditions in high impedance circuits. Deposit of active material on the surface of an insulator will reduce inter-electrode insulation and increase the risk of valve noise.

i) *Switching of tungsten-filament and thoriated tungsten-filament valves.* It is recommended that the filament current of large tungsten-filament and thoriated tungsten-filament valves should be limited when switching on from cold, and that the current should be reduced slowly when switching off. These precautions are required to minimize stress due to magnetic or thermal effects, and manufacturers' instructions normally state when they are necessary.

Convenient methods of limiting the filament current are switching in two or more steps, or the use of a saturated-core filament transformer. In general, the peak filament current should not be allowed to exceed approximately 150 per cent of the normal peak value.

205 Mounting

a) *General.* Valves are mounted in equipment by a number of methods. In many cases they are inserted into plug-in holders which provide mechanical support and electrical connections. Components used in making connections to valve terminals should be chosen with care to avoid the development of bad contacts. (See BS 448¹⁾.)

This precaution is especially important when spring loaded connections are used, for example, in valveholders for push-in mounting, since the heat developed at a poor contact tends to damage the springs and leads to progressive deterioration. Such a defect in the heater circuit will reduce cathode temperature with resultant impaired performance, and, in many cases, in reduced life. In the grid circuit a bad contact could introduce noise, or in an extreme case cause rapid failure of the valve by removing or reducing the grid bias.

b) *Vertical mounting.* It is generally desirable that valves should be mounted base downwards and in a vertical position. Many modern valves are designed for, and may be used in, other positions, but, when the manufacturer's published literature does not give any guidance, the manufacturer should be consulted before any change from the vertical method of mounting is adopted.

Mounting valves with the base upwards will affect the flow of air around the bulb and may result in the limiting temperature of the bulb or the holder being exceeded. If that part of the bulb on which the getter is deposited becomes overheated, gas will be released and the valve will become "soft". If the pinch of some valves is overheated the inter-electrode capacitance will change, and when the valves are used as oscillators, frequency drift will result. In other cases overheating of the pinch may give rise to electrolysis of the glass, resulting in breakdown. If the base is overheated the cement may contract and the base become detached from the bulb.

c) *Horizontal mounting.* Where it is necessary to mount valves horizontally, the plane of the filament of directly heated valves should be vertical. Similarly for certain indirectly heated valves having a high mutual conductance, the plane of the major axis of the control grid should be vertical.

A particular instance where this precaution is necessary is that of battery type valves where manufacturers use the minimum number of hooks for supporting filaments to obtain optimum characteristics. They also use very small clearances of the order of a few thousandths of an inch for valves of high mutual conductance. When such valves are mounted otherwise than in the upright position, they may be more microphonic or the relative movement of the electrodes may change the characteristics of the valve, or even cause failure due to contact between electrodes. The adoption of the recommendations given above reduces these risks.

d) *Mounting of small glass-based valves including miniature and sub-miniature valves.* Many of these valves employ semi-rigid pins and unless these are provided with a pin protector, the pins should be straightened in a pin straightening tool before insertion into the socket.

It is recommended that for holders with floating contacts a wiring jig be used to ensure that the holder contacts are in the correct position to receive a valve after the holder has been wired. The connections to these floating contacts should be as flexible as possible. The use of stiff wiring will destroy all the advantages provided by the float of the contacts and may hold the contacts so far out of position as to result in damage to the valve bases. The dimensions of suitable pin-straightening tools and wiring jigs are specified in BS 448¹⁾.

It is also recommended that one of the withdrawal tools designed for the purpose should be used to remove the valve from the valveholder to minimize damage to the glass base.

¹⁾ BS 448, "Electronic valve bases, caps and holders".

e) *Mounting of miniature and sub-miniature valves having flexible leads.* Valves of these types do not employ plug-in valveholders and it is usually necessary to secure them in position by the envelope. Any such method will restrict the ventilation of the envelope and care should be taken to see that the safe envelope temperature is not exceeded owing to the method of mounting used. Excessive temperature rise may often be avoided by the use of mounting clamps of high thermal capacity and conductivity placed in intimate thermal contact with the envelope. In addition, all mounting clamps should have a blackened inner surface so that heat is not reflected back into the valve.

Approximately half the cooling of an envelope in free air is due to convection, but in a well-designed metallic mounting clamp more than half the heat can be removed by conduction. Metals of high conductivity should be used and contact with the envelope should be over as large an area as possible. Efficient cooling is obtained only when the mounting clamp makes good thermal contact with the envelope and with cooler metal in the equipment.

f) *Glass-to-metal seals.* Connections having sufficient flexibility to allow for mechanical tolerances and also for thermal expansion and other movements should be employed where strains might be set up in glass-to-metal seals. These connections should be designed to avoid losses arising from poor contact and to facilitate adequate heat conduction and radiation.

g) *Spare socket-contacts.* It is undesirable to use the tags of spare valve-holder contacts as anchoring points in the circuit wiring, because of circumstances which may arise if the valve is subsequently replaced by another having different internal connections to the pins.

This practice may adversely affect the characteristics of valves with glass bases by the application of potentials to pins which are not connected to any valve element but which project into the envelope.

When a pin in the list of connections is marked "internally connected" (IC) it is particularly important that no connection be made to the corresponding valveholder tag because the pin may be supporting or interconnecting an electrode inside the valve. Such internal connections may differ for valves of a given type made by different factories or, over a period of time, they may differ during the production of a valve by one manufacturer.

h) *Soldering of rigid or semi-rigid pins.* It is undesirable to solder connections directly to rigid or semi-rigid pins in glass bases or to such leads sealed through the envelope. The application of heat introduces strain in the glass, the effect of which may not be immediately apparent, but it may subsequently impair the vacuum or crack the seal.

j) *Soldering of flexible leads.* Where valves are designed for soldering into the circuit, care must be taken to avoid bending the leads sharply close to the glass. Care must also be taken to avoid overheating the glass-to-metal seal by heat conduction along the lead. This can be avoided by the use of a thermal shunt of adequate heat capacity between the point of soldering and the glass seal. In any case the wire should never be soldered closer than 3 mm from the seals of miniature and sub-miniature types, or as specified for larger valves.

For use with miniature and sub-miniature valves the thermal shunt may conveniently take the form of a pair of pliers or a clip having attached copper jaws preferably not less than $\frac{1}{8}$ in (3.2 mm) wide. Besides protecting the seal from thermal shock it ensures that the joint cannot be made nearer the seal than the specified minimum distance. Where conditions preclude the use of a thermal shunt particular care should be taken that the temperature of the soldering iron is kept high and its application limited to the minimum time.

k) *Effects of stray fields.* The operation of valves may be seriously affected by magnetic or electro-static fields, hence they should be positioned and/or shielded so that the deleterious effects of such fields are reduced to a minimum.

The electron stream can be deflected or modulated by the stray fields from transformers, loudspeaker magnets, high-potential components and wiring thus adversely affecting the operation of the controlling electrodes. Low voltage battery valves are particularly susceptible to such effects.

l) *Insulation resistance of valve mounting.* Where a valve is followed by a high gain amplifier, the insulation of the valveholder and leads must be adequate, in relation to the magnitude of currents and voltages, to avoid the introduction of harmful effects due to leakage currents. In the case of certain valves where the input impedance is high, the introduction of minute currents or voltages due to inadequate insulation will produce serious effects in normal operating conditions, e.g. inadequate insulation in the mounting or leads of a photocell will produce random fluctuations in output; similarly, low insulation between grid and heater in a low-noise valve will cause excessive hum.

206 Ventilation

a) *Layout of equipment.* The layout and design of equipment should afford sufficient ventilation to ensure a safe envelope temperature under all conditions. The valve manufacturer normally gives the relevant information in his published data but in cases of doubt he should be consulted. As a general guide, the maximum temperature of the hottest part of the envelope under operating conditions in the equipment should not exceed by more than 20 deg C that temperature which would be obtained if the valve were operated at its maximum rating under conditions of free air circulation in a room temperature of 20 °C.

Exceptional increases of temperature may arise where valves are used in screening cans and in equipments working in tropical and/or other high ambient temperature conditions. Screening cans should only be used where necessary and they should always have black inner surfaces to prevent the reflection of heat back into the valves. Screening cans with bright inner surfaces should never be used.

Small glass based valves including miniature and sub-miniature valves with flexible leads, should be operated in free air conditions where good air circulation is possible and preferably in some form of heat-conducting shield. Where air ventilation is likely to be inadequate, heat conduction shields should always be used or the valves should be derated so that the envelope temperatures are maintained at safe levels. Material reductions in maximum envelope temperature can be achieved by the use of conduction cooling by screening cans specially designed to make close contact with the envelope (see Clause 1009).

The present trend in valve design is to reduce dimensions with the object of saving space and of improving efficiency at high frequencies, and the extent to which reduction can be made is usually limited by the amount of heat which can be dissipated from the exterior surface of the envelope.

As the proportion of heat dissipated from a valve by radiation is of the order of 50 per cent, it is necessary to allow adequate conditions for free radiation from the surface of the envelope to cooler surroundings.

The increase in the temperature of air in convective cooling is very small and it is therefore more important that the flow of air should be copious and unimpeded than that it should be particularly cold. No great risk is incurred if the air is slightly warmed by passing near other components if this allows it to flow through a less obstructed path, but valves should not be positioned adjacent to components running at very high temperatures, such as mains resistors, where direct radiation could seriously affect the envelope temperature. Somewhat different conditions apply to mercury-vapour valves; these are dealt with in Clause 504 b).

To improve radiation from the valve, surrounding surfaces should not be polished and should be kept as cool as possible.

b) *Mounting position.* When valves are mounted in other than upright positions greater care is necessary to ensure adequate ventilation so that the maximum rated temperatures are not exceeded.

c) *Free-air cooling.* Adequate ventilation is of special importance for power-amplifier valves, rectifiers, transmitting valves and mercury-vapour valves. For mercury-vapour rectifiers close control of temperature is essential. Such cases are dealt with in the appropriate sections.

d) *Forced-air cooling.* When valves designed for free-air cooling are used in conditions where free convection cannot be maintained, steps should be taken, either by a reduction in dissipation or by forced-air cooling, to ensure that the limiting envelope temperature is not exceeded. The cooling-air stream should be directed to flow evenly over the surface of the envelope except in the case of mercury-vapour valves [see Clause 504 b)].

e) *High voltages.* Particular care should be taken to maintain adequate ventilation where high voltages are concerned, to avoid insulation breakdown due to ionization or tracking.

f) *Dust precipitation.* The precipitation of dust is considerably increased at high voltages and in the vicinity of high voltage connections. This may result in insulation breakdown or variable leakage and thus may affect operation of the equipment. These effects can be avoided by use of filtered air ventilation or by regular and adequate cleaning of the affected parts, particular attention being paid to any high-voltage terminals, etc., that have sharp or pointed edges. Inadequate cleaning may increase the danger of breakdown by producing high voltage-gradients.

Oily dust precipitation is best removed by means of a cloth dampened with a suitable non-corrosive solvent (such as white spirit); scraping the envelope must be avoided.

207 Heater-cathode insulation

a) *A.C. or d.c. voltages.* An unnecessarily high potential difference between the heater and cathode should always be avoided.

The development of valves for specialized applications has resulted in a very wide range of safe maximum rated voltages which makes it impossible to quote a general safe figure. Frequently the ratings for the cathode positive to heater and those for the cathode negative to heater are widely different and such ratings should be carefully observed. Maximum ratings are normally specified in published data, but when not published, details should be obtained from the valve manufacturer.

The material, dimensions and method of applying the heater-cathode insulation are selected to give the most satisfactory compromise between the conflicting requirements of good electrical insulation and high thermal conductivity and in order to produce the modern quick-heating valve some increase in electrical conductivity has been inevitable. Even with quite low heater-cathode voltages some current may flow, while with increasing voltage the current increases (not necessarily in proportion to the applied voltage) until the insulation breaks down.

When the cathode is positive to the heater there may be some current due to emission from the heater in addition to the leakage current across the insulation.

b) *A.F. or r.f. voltages.* The insulation resistance between the heater and the cathode should not be included in r.f. circuits where frequency stability or preservation of wave-form is important, or in a.f. circuits followed by high gain.

The leakage currents make themselves apparent as noise or hum, which may assume serious proportions if the valve in which they originate is followed by a large degree of amplification. Moreover, if the heater-cathode insulation is included in a tuned circuit, any alteration to the physical or electrical properties of the insulation will alter the frequency to which the circuit is tuned, and if both r.f. and a.f. (e.g. mains-frequency) voltages exist across the insulation, there is a risk of modulation hum, particularly in cathode-coupled oscillators and the like. There is also some risk of the introduction of hum and noise due to spurious emission from the cathode as the result of the heater-cathode potential difference.

c) *Cathode keying.* The practice of “keying” by opening a cathode circuit may result in a large potential difference between heater and cathode and should be avoided. If cathode “keying” is essential a resistance not exceeding 0.25 megohm should be connected between the heater and the cathode.

Similar precautions should be taken for those valves in a radio-receiver or radiogram, the cathode circuits of which may be opened, to mute them while gramophone records are being played.

The suggested value of 0.25 megohm for the resistance is approximate only and the actual value should be determined for each circuit.

d) *Isolated heater windings.* Where a valve is operated from a separate transformer winding, it is essential that a d.c. connection should exist between this winding and the cathode to avoid heater-cathode insulation breakdown.

Where this connection does not exist a resistor of the order of 100 000 ohms should be connected between heater and cathode.

The heater will develop a potential relative to the cathode depending on the ratio of the heater-cathode insulation resistance to the insulation resistance between the heater winding and other windings, and on the voltages involved.

208 D.C. connections between the cathode and other electrodes

In no circumstances should valves be operated without a d.c. connection between each electrode and the cathode. If the connection includes a component, such as a rectifier having a resistance dependent upon the polarity or magnitude of the voltage applied to it, care should be taken to ensure that the electrode can never attain a potential uncontrolled with respect to the associated cathode.

The total effective resistance between any electrode and the cathode should be the minimum practicable. It is important to remember that any apparent advantage of an “open-circuited” electrode or of a high-resistance path may be lost because of a secondary emission characteristic of the valve.