GENERAL OPERATIONAL RECOMMENDATIONS

1. GENERAL

Failure to observe these General Operational Recommendations may seriously reduce the life of a valve and in some instances could result in catastrophic failure.

Any enquiries should be addressed to the Government and Industrial Valve Division, Mullard Limited.

2. CHARACTERISTICS

The published characteristics are based upon averages of readings taken on a representative number of valves.

3. LIMITING VALUES

The limiting values whether maximum or minimum are absolute and the following definition of the absolute system has been based on that agreed by the International Electrotechnical Commission.

3.1. Absolute-maximum rating system

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

These values are chosen by the valve manufacturer to provide acceptable serviceability of the valve, taking no responsibility for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the valve under consideration and all other electron devices in the equipment.

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

In some instances, such as with very short pulse durations or complex wave trains, it may be permitted to exceed the absolute values, but the desired operating conditions must be agreed with Mullard Limited.

4. TYPICAL OPERATING CONDITIONS

Typical operating conditions are given, some of which 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.

Where several typical operating conditions are given, interpolation for intermediate conditions is generally permitted. There are exceptions to this rule and the operating conditions should be agreed with Mullard Limited.

5. INSTALLATION

Ferrous tools must not be used on permanent magnet valves, as this may cause deterioration in the performance of the valve. Any glass or ceramic insulation supporting the cathode terminal should be carefully cleaned when necessary since pulse current leakage could cause irregular transmission and damage through local heating. In addition the outlet flange must be clean in order to discourage arcing.

6. 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.
204: 1960	Glossary of terms used in telecommunications (including radio) and electronics.

GENERAL OPERATIONAL RECOMMENDATIONS

1. HEATER

To obtain maximum life the heater voltage must be within $\pm 2.5\%$ of the nominal value and temporary fluctuations must be within $\pm 10\%$.

2. HEATER-TO-CATHODE VOLTAGE

If a valve is operated with the delay structure earthed, care must be taken not to exceed the heater-to-cathode voltage rating.

3. DELAY STRUCTURE

The delay structure of certain types of valves can be operated above earth potential as it is isolated from the magnet system and the output connection. Reference should be made to the individual data sheets.

4. CONTROL GRID

The control grid must never be allowed to become positive with respect to the cathode.

5. COOLING

The maximum valve temperature should on no account be exceeded and it may be necessary to provide additional cooling to prevent the temperature limits being exceeded, especially where electromagnetic focusing is used.

6. FOCUSING MOUNTS

Suitable magnetic focusing fields are provided by the valve mounts available from Mullard Limited.

With an electromagnetic focusing system, the solenoid current must be stabilised.

7. OPERATING SEQUENCE

The following sequence should be followed.

No mechanical focusing adjustments are required as the valves are supplied prealigned for insertion in a mount.

a. Switch on the power supply of the electromagnetic focusing system.

b. Apply heater voltage.

c. The electrode voltages may be applied simultaneously but it is preferable that the control electrode voltage be delayed with respect to the other electrode voltages. The anode voltage must never be applied in the absence of the delay structure voltage.

8. SWITCHING OFF

All the electrode voltages may be removed simultaneously but it is preferable for the anode voltage to decrease more rapidly than the other electrode voltages. Where an electromagnetic focusing arrangement is used the valve electrode voltages must be removed before switching off the solenoid power supply.

9. POWER SUPPLIES

9.1. Protective circuits

Protective devices are desirable to prevent damage to the valve if the valve power supply or the solenoid power supply cooling arrangements fail.

9.2. Regulation

The stability of the output frequency will be primarily dependent upon the regulation of the voltage applied to the delay structure. Variation of the heater, grid and anode voltages have a secondary effect.

10. POWER OUTPUT CONTROL

The power output may be controlled over a limited range by controlling the beam current. This is achieved by varying the grid or anode voltages.

If the grid is used to control the power output an additional power supply with a negative output voltage will be required. This has the advantage of presenting a high impedance to the control signal. When the anode is used as the control electrode the grid may be connected to the cathode.

11. AMPLITUDE AND PULSE MODULATION

Amplitude modulation can be achieved by modulating either the grid or anode. The most suitable electrode is the grid because of the high impedance presented to the signal source.

12. FREQUENCY MODULATION

Frequency modulation can be achieved by modulating the delay structure voltage. If a wide frequency deviation is used, the power output will fluctuate across the band. This may be corrected by sampling the output signal and feeding a voltage back to the grid.

13. SHIELDING

Any disturbance of the focusing field may impair the performance of the valve and the valve must be protected from the effects of nearby ferrous material and stray magnetic fields.

The degree of susceptibility to such interference varies for different focusing systems and specific information will be given in the individual data sheets. Unless magnetic shielding or component orientation is adopted ferrous objects should be kept more than 9 inches away and other magnetic objects should be positioned 18 inches from the valve.

14. STORAGE

Backward-wave oscillators should be stored in their original packing to protect the valve against reasonable vibration and knocks. This also ensures that the spacing between permanent magnet valves and other magnets or ferrous objects is adequate to avoid reduction of magnetisation.

Unpacked permanent magnet valves should **NEVER** be placed on steel benches or shelves.

GENERAL OPERATIONAL RECOMMENDATIONS

1. HEATER

1.1. Low noise values

To obtain the minimum noise figure the heater voltage must be within ±2.5% of the specified value and temporary fluctuations must be within ±5%.

1.2. Intermediate and power values

To obtain the maximum life the heater voltage must be within ±2.5% of the nominal value and temporary fluctuations must be within ±10%.

2. COOLING

It may be necessary to provide additional cooling to prevent the valve and focusing system temperature limits being exceeded.

Forced cooling of the collector terminal may be required and recommendations will be given in the individual valve data.

Normally cooling of electromagnetic focusing systems will be required.

3. FOCUSING MOUNTS

A suitable magnetic field is provided by the mounts available from Mullard Limited.

Designers who do not propose to use one of these mounts should consult the valve manufacturer as an unsuitable mount can impair the performance of the valve. In many instances, the focusing mount incorporates the radio frequency input and output connections with suitable matching devices.

Focus alignment screws are provided on the approved mounts and a presetting procedure for these has been established (see appropriate data sheets). This procedure will reduce the risk of damage to the valve due to excessive helix dissipation during the focusing operations.

4. SHIELDING

Any disturbance of the focusing field may impair the performance of the valve, and the valve must be protected from the effects of nearby ferrous material and stray magnetic fields.

The degree of susceptibility to such interference varies for different focusing systems and specific information will be given in the individual data sheets. Unless magnetic shielding or component orientation is adopted ferrous objects should be kept more than 9 inches away and other magnetic objects should be positioned 18 inches away from the valve.

5. POWER SUPPLIES

5.1. Protective devices

Protective devices are desirable to prevent damage to the valve if the power supply or cooling arrangements fail.

5.2. Regulation

The regulation requirements can be determined with reference to the typical curves of gain, phase shift and electrode voltages.

The change in gain with electrode voltage is usually greatest for the current controlling electrode (normally the first grid) and the helix.

Any ripple voltage on the helix will give rise to phase modulation of the signal.

With an electromagnetic focusing system the solenoid current must be stabilised.

6. INSTALLATION SEQUENCE

When putting a valve into operation the initial adjustments should be made in the following order:

Ensure that the control electrode voltage is set at zero and then apply simultaneously the remaining electrode voltages and adjust in accordance with recommended values. Increase the control electrode voltage until cathode current is drawn, ensuring that the maximum helix current limit is not exceeded. Adjust the focus alignment screws so that the helix current is a minimum and the collector current is a maximum. Repeat this procedure until the required collector current is achieved and the helix current is a minimum. A typical helix current is given in the valve data under operating conditions.

Inject a low level radio frequency signal at the desired operating frequency ensuring that the value is not saturated and observe the output level. Adjust the helix voltage until a maximum output level is achieved. Recheck for optimum focusing and lock focus alignment screws.

7. OPERATING SEQUENCE

The following sequence should be followed:

a. Apply the heater voltage and allow the specified heater warm up time.

b. Switch on the power supply of the electromagnetic focusing system.

c. The electrode voltages may be applied simultaneously but it is preferable that the control electrode voltage be delayed with respect to the other electrode voltages.

8. SWITCHING OFF

All the electrode voltages may be removed simultaneously but it is preferable for the control electrode voltage to decrease more rapidly than the other electrode voltages.

Where an electromagnetic focusing arrangement is used the valve electrode voltages must be removed before switching off the solenoid power supply.

9. STORAGE

The valve should be stored in its original packing, which is designed to give reasonable protection against vibration and knocks. This also ensures that the spacing between permanent magnet valves and other ferrous objects is adequate to avoid reduction of magnetisation.

Unpacked permanent magnet valves should **NEVER** be placed on steel benches or shelves.

GENERAL OPERATIONAL RECOMMENDATIONS

The following recommendations should be interpreted in conjunction with British Standard Code of Practice No. CP1005: 'The Use of Electronic Valves', Part 9, upon which these notes have, in part, been based.

1. HEATER

1.1. General

A cathode temperature either too high or low may lead to unsatisfactory operation such as moding and arcing, involving short life and loss of efficiency.

During operation the cathode temperature is increased by electron bombardment ('back heating'). The data sheets for magnetrons, therefore, usually contain information relating the heater voltage to the average anode input power so that the cathode temperature can be maintained at the desired level.

The heater voltage should be at the stated nominal when the h.t. is first applied, and be subsequently reduced as recommended in the data. In the case of magnetrons having cathodes of small thermal capacity, it may be necessary to reduce the heater voltage immediately the anode voltage is applied.

With some valves it may be required to limit the filament or heater current when switching on the supply. Information on this will generally be included on individual data sheets.

1.2. Indirectly heated oxide-coated cathodes

To obtain maximum life the heater voltage must be within $\pm 5\%$ of the value recommended for a particular operation.

1.3. Directly heated cathodes

Reference should be made to the individual data sheets.

2. INPUT AND OUTPUT CONNECTIONS

2.1. Input connection

The negative input voltage should be applied to the common heater-cathode terminal to avoid the flow of anode current through the heater which might be damaged.
In applications where a bifilar pulse transformer is used a non-inductive capacitor should be connected between the heater-cathode and heater terminals to suppress any high transient voltages.

2.2. Output connection

It is important that the type of output connection should be as specified in the data. Use of flat coupling instead of choke coupling or vice versa may upset the matching and possibly cause breakdown of the output system. Connections to the output must be designed to be sufficiently tight to avoid arcing and other faults. It is also important to avoid undue stressing of the output section which would either deform the metal or break the glass or ceramic vacuum seals. It is, therefore, necessary that any mechanical pressure be applied uniformly.

3. H.T. SUPPLY AND MODULATORS

3.1. General

The dynamic impedance of magnetrons is in general low; thus small variations in the applied voltage can cause appreciable changes in operating current. In the equipment design it is necessary to ensure that such variations in operating current do not lead to operation outside the published limits.

Current changes result in variation of power frequency and frequency spectrum quality and consequent deterioration of equipment performance. This factor should determine the maximum current change inherent in the equipment design under the worst operating conditions.

3.2. C.W. types

For c.w. types the amount of smoothing required in the h.t. supply depends on the amount of modulation, resulting from operating current variation, which can be tolerated.

Under certain operational conditions a c.w. magnetron can develop a negative resistance characteristic and a minimum value of series resistance which should be adjacent to the magnetron is given in individual data sheets.

3.3. Pulse types

To ensure a constant operating condition with a pulsed valve the modulator design must provide a pulse, the amplitude of which does not vary to any significant extent from pulse to pulse. The necessary design precautions depend on the type of modulator employed, and cannot be generalised.

The performance of a magnetron is often a sensitive function of the shape of the pulse that it receives and it is necessary to control four distinct aspects: rate of rise, spike, flat and rate of fall. In this connection it is important that any observation of the shape of the pulse, either of voltage or of current, supplied by the modulator should be made with a magnetron load and not with a dummy load, because a magnetron acts as a non-linear impedance. Furthermore, a magnetron is likely to be more sensitive to a mismatched load.

3.3.1. Rate of rise

Both maximum and minimum rates of rise of voltage (and sometimes current) may be specified. The most critical value is that just before and during the initiation of oscillation. Too high or low a rate of rise may accentuate the tendency to moding.

Too high a rate of rise may cause operation in the wrong mode or even failure to oscillate, and either of these conditions may lead to arcing due to overheating or to excessive voltages.

Operation at too low a rate of rise may also cause oscillation in the wrong mode or oscillation in the normal mode for an appreciable period at less than full current and this will cause frequency pushing leading to a broad frequency spectrum.

The rate of rise of voltage should be measured above the 80% point of the peak voltage corresponding to the onset of oscillation. For accuracy it is advisable to measure the rate of rise by means of a differentiating circuit whose total capacitance does not exceed 5% of the total stray capacitance of the modulator output circuit. Direct observation on an oscilloscope can be misleading due to the limitation of the oscilloscope and sampling device.

3.3.2. Spike

It is important that the voltage pulse should not have a high spike on the leading edge. Such a spike may cause the valve to start in an undesired mode. Although this operation may not be sustained, the transient condition may lead to destructive arcing. Measures taken to reduce the spike must not also reduce the rate of rise below the specified minimum.

3.3.3. Flat

The top of the voltage pulse should be free from ripple or droop since small changes in voltage cause large current variations resulting in frequency pushing. This leads to frequency modulation of the r.f. pulse and consequent broadening of the spectrum or instability.

3.3.4. Rate of fall

The fall of voltage must be rapid at least to the point where oscillation ceases, to avoid appreciable periods of operation below full current, with the attendant frequency pushing. This point is normally reached when the voltage has fallen to about 80% of the peak value.

Beyond this point a lower rate of fall is generally permissible, but a significant amount of noise will be generated, which may be detrimental to radar systems with a very short minimum range. To prevent coherent noise being generated especially in short range radars the voltage tail must decay to zero before the radar receiver recovers.

A fast rate of fall is also important where valves are operated at a high pulse recurrence frequency since any diode current which occurs after oscillations have ceased will add appreciably to the mean current and dissipation of the valve.

In certain applications it is desirable to return the valve cathode to a positive d.c. bias in order to speed up the rate of fall and to prevent diode current being passed during the inter-pulse period.

4. LOADING

The anode current range shown in individual data sheets is related to a maximum standing wave ratio seen by the magnetron of 1.5 to 1. Incorrect loading beyond this may reduce the current range for stable operation and can cause arcing or moding.

5. GENERATOR LOAD CHART (Rieke diagram)

A chart showing typical output power and frequency change plotted on a modified impedance circle diagram against magnitude (v.s.w.r.) and phase of the load seen by the magnetron, provides information on the behaviour of the magnetron to different load conditions.

Such a chart is often referred to as a Rieke diagram.

6. PHASE OF SINK

From the generator load chart it is seen that with a load of bad mismatch and at a particular phase, there is a region on the chart which is characterised by high power output and convergence of the frequency contours. This region is known as 'the sink' and the phase of the load at which the magnetron behaves in this manner is known as 'the phase of sink'. Operation of the magnetron under this load condition will lead to instability and may cause failure of the magnetron. By matching the r.f. system such that the maximum permitted load v.s.w.r. is not exceeded, the sink will be avoided.

7. OPERATION IN DUPLEXER SYSTEMS

7.1. Position of t.r. cell

Where the r.f. systems incorporates a t.r. cell a bad load mismatch, which is unavoidable, is seen by the magnetron momentarily until the cell has been ionised. If the phase of this mismatch is such that it is in the phase of sink the build up of oscillation of the magnetron may be prevented. It is therefore essential that the t.r. cell is so positioned that its phase of mismatch as seen by the magnetron is remote from the sink region.

7.2. Position of minimum

In the non-oscillating condition the magnetron presents at its frequency of oscillation a bad mismatch of considerable magnitude to the r.f. system. This property is utilised in certain duplexer systems. In the design of such a system it is necessary to know the phase of the above load mismatch and this is designated at a position of minimum of the voltage standing wave in relation to a reference plane on the magnetron output system.

8. COOLING

8.1. General

The maximum temperature of the anode block, cathode terminal assembly and waveguide windows, where applicable, should on no account be exceeded. It may be necessary to provide additional cooling to prevent these temperature limits being exceeded. Where air or water cooling is necessary, interlock switches should be provided to prevent operation in the event of failure or reduction of cooling medium. 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 means may be used.

8.2. Air cooling

For the cooling of components such as input waveguide windows and output domes it is important that the air should not contain dust, moisture or grease.

8.3. Water cooling

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.

9. PRESSURISATION

The limiting values and operating conditions quoted in the data are given for a pressure of 650mm of mercury unless otherwise stated. In the case of high power magnetrons it may be necessary to pressurise the output waveguide in order to prevent electrical breakdown. Advice is given in the individual valve data sheets. Precautionary steps should be taken to prevent operation in the event of the failure of the pressurisation. In order to avoid dielectric breakdown, clean and dry air or gas must be used.

10. STORAGE

Valves should be stored in their original packing because this has been designed to protect the valve against reasonable vibration, and knocks. It also ensures that the spacing between permanent-magnet valves and other magnets or ferrous objects is adequate to avoid reduction of magnetisation. Despite this controlled spacing, magnetically-sensitive instruments such as compasses, electrical meters and watches should not be brought close to a bank of packaged magnetrons.

When a valve is protected by a moisture-proof container this fact is clearly stated on the outside. Unnecessary opening of the seal should be avoided so that the dessicant is not exhausted rapidly. When a magnetron is temporarily taken out of service it should be placed immediately in its proper container. This is a good practice which obviates the risk of damage to the magnet or to the glass or ceramic parts and prevents the entry of foreign matter into the output aperture.

Unpacked permanent-magnet valves should **NEVER** be placed on steel benches or shelves.

11. CONDITIONING

It is recommended that after transit or a long period of storage the anode voltage should be increased gradually or in several steps until normal operation is achieved. This treatment will clean up any traces of gases which could cause arcing or instability and this procedure is particularly important in high power magnetrons.

12. RADIATION HAZARDS

In general the shorter the wavelength of an r.f. radiation the greater the absorption by body tissues and hence for comparable power, the greater the hazard. With magnetrons the power may be sufficient to cause danger, particularly to the eyes.

If it is necessary to look directly into a magnetron output, this should be performed through an attenuating tube or through a small hole set in the wall of the waveguide at a bend. Alternatively r.f. screening such as copper gauze of mesh small compared with the wavelength must be provided.

With high power magnetrons precautions may also be necessary to reduce the stray r.f. radiation emitted through the cathode stem and other apertures, especially when the magnetron is functioning incorrectly.

High voltage magnetrons (as well as the high voltage rectifier and pulse modulator valves) can emit a significant intensity of X-rays and protection of the operator may be necessary. When magnetron behaviour is viewed through an aperture X-rays may be present. Protection of the eye is afforded by viewing through lead glass.

GENERAL OPERATIONAL RECOMMENDATIONS

1. HEATER

The heater voltage unless otherwise specified in individual data sheets must be set within $\pm 7\%$ of the nominal value and temporary fluctuations must be within $\pm 10\%$. Where freedom from undesirable modulation is important a d.c. stabilised heater supply should be used.

2. CONTROL GRID

This electrode when incorporated is used to control the resonator current and the nominal voltage is specified in the data for individual types.

The control grid must never be allowed to become positive with respect to the cathode.

3. RESONATOR

This electrode is usually connected to the body of the valve and is normally operated at earth potential.

4. REFLECTOR

To avoid damage to the valve the reflector potential must never become positive with respect to the cathode and for this reason it is essential that the reflector connection be made at all times during operation.

If a high impedance reflector voltage supply is used, the time constant should be such that the resonator voltage is not applied before the reflector has become negative with respect to the cathode.

5. MODES OF OSCILLATION

A reflex klystron may be operated in several modes which are determined by transit time effects and are dependent upon the reflector voltage. The mode of operation is chosen for optimum power output and for the maximum electronic tuning range.

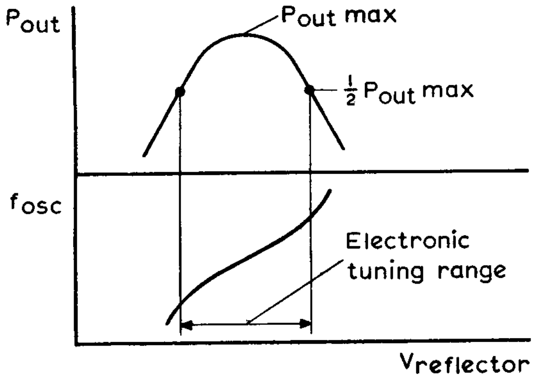
6. TUNING

6.1. Electronic tuning

The frequency of oscillation within a mode may be varied by adjusting the reflector voltage. The frequency change between the frequencies at which the power output has fallen to half the maximum value is defined as the electronic tuning range.

6.2. Mechanical tuning

Generally klystrons can be mechanically tuned over a wide frequency range but it is necessary to optimise the reflector voltage for maximum power output at the required frequency.



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7. MODULATION

7.1. Frequency modulation

Frequency modulation may be achieved by applying a modulating voltage to the reflector electrode. To minimise distortion, the amplitude of the modulation signal should be small compared with the voltage required to achieve the electronic tuning range. The most linear frequency modulation characteristic is normally obtained with the reflector voltage optimised for maximum power output at the required carrier frequency.

7.2. Pulse modulation

The output of a reflex klystron may be pulsed by modulating the reflector or control electrode voltage. To minimise frequency modulation effects the modulating signal should be as near rectangular as possible.

The reflector voltage is adjusted so that the valve is not oscillating and the amplitude of the modulating signal should be the difference between this voltage and the reflector voltage required to give optimum power output at the required frequency. The amplitude of the modulating voltage must not cause the valve to oscillate in more than one mode and the static reflector voltage should be chosen accordingly.

8. FREQUENCY STABILITY

The frequency of oscillation is primarily dependent upon the applied voltage between the reflector and resonator and the valve should be operated from a well regulated power supply.

Variations of the ambient temperature, load, atmospheric pressure, and heater voltage have a secondary effect.

9. LOAD MISMATCH

Care must be taken to minimise load reflections, as a change of phase of the mismatch will cause frequency pulling and variation in the power output. A severe mismatch may cause the valve to cease oscillating over portions of the tuning range.

10. TUNING MECHANISM

Information on the number of turns of the tuning mechanism required to cover the prescribed tuning range is given in the individual data sheets.

Adjustment of the tuning mechanism beyond the stated frequency limits must not be attempted. Where the mechanical tuning is achieved by adjustment of a cavity within the evacuated envelope by means of a flexible diaphragm the number of tuning cycles may be limited to avoid damage to the diaphragm.

11. SHIELDING

The resonator and reflector leads should be screened to shield the valve from induced modulation.

12. COOLING

Adequate cooling to prevent the maximum temperature limits being exceeded is required particularly when the valve is enclosed in a protective shield.

13. MOUNT

The performance quoted in the individual data sheets for those valves which have a coaxial lead output is dependent upon the use of the specified coaxial to waveguide transition unit.