Valve heating time

The time required for a valve to attain minimum operating temperature with normal voltage applied to the heating element. For a mercury vapour valve this time is generally much longer than that required to bring the cathode to the normal operating temperature.

Anode voltage drop

The potential difference between anode and cathode or midpoint of the filament during the time when the valve is conducting.

Critical grid voltage

The instantaneous value of grid voltage at which anode current commences to flow.

Control characteristic

The relationship between the critical grid voltage and the anode voltage. This is usually depicted graphically.

Positive current

Conventional current flowing into the valve through the electrode named.

Critical grid current

The instantaneous value of grid current immediately before anode current commences to flow.

Commutation factor

The product of rate of decay of anode current (A/μs) immediately prior to current extinction, and the initial rate of rise of the inverse anode voltage (V/μs) immediately following extinction of current.

Recovery time (Deionisation time)

The time between the cessation of anode current and the instant when the grid regains control.

Ionisation time

The time required for the anode current to rise to 90 per cent of its rated peak value, the time being measured from the instant of application of critical grid voltage (see also Anode Delay Time).

Maximum averaging time

The longest period of time over which it is permissible to compute the maximum average value of the characteristic under consideration.

Anode delay time

The interval between the time when the rising portion of the grid pulse would reach 26% of its full amplitude if it were unloaded and the instant when anode conduction takes place.

Jitter

The maximum variation of anode delay time from pulse to pulse.

Condensed mercury temperature

The temperature of the external surface of that part of the valve envelope at which the mercury is seen to condense during normal operation of the valve.

The following recommendations should be interpreted in conjunction with British Standard Code of Practice No CP1005: Parts 1 and 2: 1954, 'The Use of Electronic Valves', upon which these notes have, in part, been based.

LIMITING VALUES

The operating limits quoted on data sheets for individual valves should on no account be exceeded. Two methods of specifying limiting values are used, the 'absolute' and 'design centre' systems, and these should be interpreted as follows:

Absolute Ratings

The equipment designer must ensure that these ratings are never exceeded and in arriving at the actual valve operating conditions variations caused by mains fluctuations, component tolerances and switching surges must be taken into account.

Design Centre Ratings

With a set of nominal valves inserted in an equipment connected to the highest permitted nominal supply voltage within a given tapping range, and in which all components have their nominal value, the valve operating conditions may at no time exceed the published maximum design centre value. The phrase 'at no time' in the above paragraph means that increases in the valve working conditions, due to operating changes in equipment (e.g. switching, etc.), should be taken into account by the equipment designer. Mains voltage variations (of up to $\pm 6\%$) are allowed for in the valve ratings, provided good practice is followed in the design of the equipment.

FILAMENT OR HEATER SUPPLY

Unless otherwise stated the filament or heater voltage of a thyratron should be set within $\pm 2{\cdot}5\%$ of the nominal value. Temporary mains fluctuations up to $\pm 6\%$ are permissible. To ensure maximum life from a directly heated valve the filament supply should be $90^\circ \pm 30^\circ$ out of phase with the anode supply unless otherwise specified. Measurement of the filament or heater voltage should be made at the valve pins.

VALVE TEMPERATURE LIMITATIONS

The ratings published for Mullard mercury vapour thyratrons apply only when they are operated within the limits stated for the temperature of the condensed mercury.

With the filament or heater voltage applied, the time required to reach the minimum permissible condensed mercury temperature is a function of the ambient temperature and can be determined from the heating and cooling characteristic. Thus a direct measurement of the condensed mercury temperature, although desirable, is not essential. Ideally, no cathode current should be drawn until the filament or heater supply has been on for this time, but in practice little damage is done if the current is drawn when the condensed mercury temperature is within 5 or 10°C of the minimum permissible value (see individual data sheets). Thus with normal usage, where the valve is started only two or three times per day, an adequate life can still be obtained with a reduced heating time. The ambient conditions, however, must be such that the minimum permissible condensed mercury temperature is eventually reached and the filament or heater voltage must be within the specified tolerances. In any case the heating time must not be less than the specified minimum cathode heating time.

It is necessary to provide adequate ventilation around the valve so that the maximum ambient or condensed mercury temperature is never exceeded for any condition of loading. This avoids the danger of arc-back. Whenever it may be necessary to check the condensed mercury temperature of thyratrons the following procedure is recommended. A temperature indicator of low thermal capacity, such as a fine-wire thermocouple, should be attached to the valve at the mercury condensation point by the minimum amount of adhesive. Care should be taken to ensure that other conditions of operation, such as load current, ambient temperature of the air outside the equipment, and the ventilation remain unchanged during the measurement.

With inert-gas thyratrons ambient temperature limitations are given and in general it is only necessary to employ the minimum cathode heating time before switching on.

CURRENT RATINGS

For each rating of maximum average current, a maximum averaging time is quoted. This is to ensure that current greater than the maximum permissible average value is not drawn for such a length of time as would give rise to an excessive temperature within the valve. For periods less than the maximum averaging time it is permissible to draw average currents greater than the maximum rated value provided that the product of this current and time does not exceed the product of the maximum rated average current and the maximum averaging time. When more than one value of peak current is quoted depending upon the frequency of operation, this must be taken into consideration.

SHORT CIRCUIT PROTECTION

The figure given on each data sheet for maximum surge (fault protection) cathode current is intended as a guide to equipment designers. It indicates the maximum value of current, resulting from a sudden overload or short circuit, which the thyratron will pass for a period not exceeding 0·1 second without resulting in its immediate destruction. Several overloads of this nature, will, however, appreciably reduce the life of the valve. When thyratrons are used as grid-controlled rectifiers it is advisable to include a fuse of suitable rating in the anode circuit of each valve.

POWER SUPPLY FREQUENCY LIMITATIONS

In general, when thyratrons are operated at frequencies below 25c/s, a lower maximum peak cathode current is applicable. This is necessary to ensure that cathode fatigue does not result. The maximum frequency at which a thyratron will operate satisfactorily is dependent upon the recovery time and therefore upon the conditions of operation. At higher frequencies the valve will fail to operate due to arc-back and loss of grid control. When operation at high frequencies is desired the commutation factor should be kept as low as possible in order to ensure satisfactory life.

EFFECTS OF POSITIVE ION CURRENT

When a thyratron is conducting, a positive ion current of magnitude proportional to the cathode current is generated. This current will, in general, flow to that electrode which is at the most negative potential during conduction. In order to prevent damage to the valve it is necessary to ensure that the voltage of this electrode is more positive than −10V during this phase. This precaution will prevent an increase in electrode emission due to excessive electrode dissipation, sputtering of electrode material, changes in the control characteristics caused by shift in contact potential and, in the case of inert gas-filled valves, a rapid gas clean-up. In circuits where the control grid is held negative during anode conduction, a suitable choice of resistor in series with the grid will maintain an effective grid bias more positive than –10V. The minimum value of the resistor may be determined from the grid ion current characteristic. If the instantaneous value of anode current is low then the restriction on grid bias does not apply. In general, the grid should be more positive than –10V for all values of anode current greater than 10 per cent of the rated maximum average current. In circuits where the anode potential changes from a positive to a negative value and the control-grid is at a positive potential, thereby drawing cathode current, a small positive ion current flows to the anode. In such a case the inclusion of a high value of anode resistor is precluded by circuit requirements, as the anode will usually reach a high negative potential. It is essential to limit the magnitude of the positive ion current by severely restricting the current flowing from cathode to grid. This may be effected by using the maximum permitted series grid resistor and/or alternatively, keeping the positive grid voltage swing as low as possible.

In those circuits where the anode potential changes very rapidly from a positive to a high negative value, such as with inductive loads fed from polyphase supplies, there will be residual positive ions within the valve which will be drawn towards the anode with considerable energy. In the case of an inert gas-filled valve this will result in excessive gas clean-up and it is therefore necessary to observe the limitations imposed by the appropriate commutation factor.

PARALLEL OPERATION OF THYRATRONS

Thyratrons cannot normally be operated directly in parallel. An alternative arrangement must be adopted if a higher current output is required. Information on suitable methods will be supplied on request.

USE OF CONTROL CHARACTERISTICS

In most cases the control characteristic given on the data sheets is shown by upper and lower boundary curves within which all valves may be expected to remain during life. The control characteristic of a particular valve may move within these boundaries although, as a rule, these limits should be considered as extreme cases. This should be taken into consideration when designing grid excitation circuits for thyratrons.

SCREENING AND R.F. FILTER CIRCUITS

(*a*) In order to prevent spurious ionisation of the gas or mercury vapour (and consequent flash-over) due to strong r.f. fields, it may be necessary to enclose the thyratrons in a separate screening box. For the same reason r.f. filters should be used to prevent high frequency current circulating in the thyratron circuits via the wiring.

(*b*) High frequency disturbances, usually due to oscillation in the transformer windings and associated wiring, are often produced by gaseous valves, and may cause interference in apparatus situated near the thyratron unit. Small r.f. chokes or resistors in the anode leads will generally reduce the interference, and screening as recommended in paragraph (*a*) above may also be adopted, with r.f. filters in all leads emerging from the screen.

INSTALLATION

Mercury vapour thyratrons should always be mounted vertically with the cathode connections at the lower end. When a mercury vapour thyratron is first installed, and before it is put into service, it should be run for at least half an hour at its normal heater or filament voltage but without any other electrode voltages applied in order to vaporise any mercury which may have been deposited upon the electrode assembly during transit. This precaution should also be taken before putting into service a mercury vapour valve which has been out of use for any considerable time.

The mounting requirements for inert gas thyratrons are less stringent and are specified for each valve.

ADDITIONAL NOTES FOR HYDROGEN THYRATRONS

HEATER AND REPLENISHER VOLTAGES

The heater and replenisher voltages should be maintained within the rated limits, to avoid abnormal hydrogen or gas pressure. This might cause premature failure of cathode emission, gas clean-up, excessive anode dissipation or continuous conduction.

CURRENT RATINGS

For each rating of maximum average current a maximum averaging time is quoted. This is to ensure that an anode current greater than the maximum average value is not drawn for such a length of time as would give rise to excessive temperature within the valve. The maximum peak anode current is determined by the safe cathode emission, whereas the average current is limited by its heating effects.

SHORT CIRCUIT PROTECTION

Failure of the thyratron to regain control at the end of a current pulse may occur at the first or second attempt of instantaneous starting or as a result of an adverse mismatch occurring between the pulse forming network and load impedance; for example this may occur when a magnetron fails to oscillate. In the event of such a failure the thyratron mean current will rise considerably and a circuit breaker or fuse which will act within 0·1s with 200% current overload should be incorporated to avoid the destruction of the thyratron.

RATINGS INTER-RELATION PRODUCT

A limitation placed on the product of peak anode voltage, peak anode current and pulse repetition frequency which is designed to avoid excessive power dissipation in the valve.

COMMUTATION

When the thyratron is conducting, the number of positive ions generated is proportional to the cathode current. After the cessation of anode conduction several microseconds elapse before the number of positive ions has substantially diminished.

If the anode develops a high negative potential immediately after the current pulse, these ions will bombard the anode and this may result in excessive anode dissipation and gas clean-up. A special inverse voltage rating, applicable for a period of 25μs after each current pulse, is therefore specified for each valve type.

RECOVERY TIME

A delay must be allowed between the cessation of the current pulse and the re-application of anode voltage. This will ensure that the concentration of ions has decayed to a level which will not cause spurious anode firing. The recovery time may be minimised by providing a low impedance d.c. path from grid to cathode (e.g. the secondary coil of a suitable pulse transformer) or by applying a negative bias to the grid. The necessary delay between the cessation of anode current and the rise of anode voltage may, in many applications, be produced by allowing the anode voltage to swing negative after the current pulse. A minimum overswing of 5% of the peak forward voltage is normally specified. (The danger of an excessive overswing has already been mentioned under Commutation.)

The rapid rise of anode voltage is delayed further if the pulse-forming network is charged through an inductor rather than through a resistor.

GRID EXCITATION CIRCUIT

Hydrogen thyratrons are usually designed with positive firing characteristics so that a negative bias is not essential. Normally a grid current of several milliamperes must be drawn before anode conduction is initiated. A steeply rising grid voltage derived from a source of low impedance should ensure a small and steady anode delay time. A maximum rise time and source impedance are specified on individual data sheets.

INSTALLATION

Hydrogen thyratrons may be mounted in any position and, if desired, the valve may be clamped, preferably on the base. If the clamp is applied to the envelope it should have a low thermal inertia and should not be applied above the point specified on the individual data sheet. The anode lead should be arranged so that it is not close to the glass envelope and the valve should be screened from r.f. fields.

An air blast may be used to cool the anode lead if necessary but it must not be directed upon the glass envelope of the valve.

Hydrogen thyratrons may emit harmful X-radiation and should be suitably screened to protect personnel.