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Klystrons

Plug-in Reflex Klystrons for Microwaves

by

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E.M.I. ELECTRONICS LTD.
Hayes, Middlesex,
England

Reprinted from
JOURNAL OF ELECTRONICS AND CONTROL
December, 1957
Published by
TAYLOR & FRANCIS LTD., Red Lion Court, Fleet Street, London, E.C.4

ELECTRONICS SECTION

Plug-in Reflex Klystrons for Microwaves†

By A. F. PEARCE‡, K. H. KREUCHEN‡, C. BARON§, N. HOULDING||, and S. RATCLIFFE§

[Received August 7, 1957]

SUMMARY

Plug-in reflex klystrons, which have recently been developed, have many advantages ; these include flexibility of cavity design, low replacement cost, improved consistency of characteristics, and a reduction in the number of types of valve needed to cover a wide frequency band.

The factors upon which the performance depends are discussed from the particular point of view of plug-in applications. Constructional details and characteristics are given for two valves so far completed ; these are, CV2116 for the S-band and CV2346 for the X-band, and both are low-voltage tubes. The former gives an output power of over 150 mw and the latter about 40 mw over a frequency band of about 20%, but tests have shown that, given suitable cavities, these two valves have a useful performance between 2 and 12 kMc/s.

The principles of the design of cavities suitable for these valves are discussed, with some typical examples.

CONTENTS

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§ 1. INTRODUCTION

THE development of new local oscillator klystrons was initiated as part of the general programme of improvement of microwave radars. Improved consistency of characteristics was required in order to reduce the need for adjustable elements in the automatic tuning circuits (Ratcliffe 1954). At the same time the design should be such as to contribute, in every possible way, to the overall reliability of the equipment, and to be well suited to systems using mechanical A.F.C.

It was soon apparent that these requirements could best be met by a valve of the disc seal type, which plugs in to a cavity, despite the objections which led earlier workers (Pierce and Shepherd 1947, p. 570) to abandon this approach in favour of the integral resonator klystron as exemplified by the 723A/B. The main disadvantage of the plug-in valve is a direct consequence of one of its biggest assets ; the valve is so flexible in application that an inexperienced designer may attempt to use it in an unsuitable cavity and blame the valve for unsatisfactory results. This did not seem to constitute a sound objection, for, after all, this situation is not novel and similar difficulties can be experienced with integral cavity valves which are coupled to a mismatched load.

Another difficulty to be expected was that of overcoming prejudice among some equipment designers against the plug-in valve as opposed to one with an integral cavity, and of ensuring that the difficulties of designing a cavity were not overestimated and the advantages of the plug-in valve fully understood. These advantages are as follows.

1.1. *Rationalization*

Valves with built-in cavities are of limited application, and many variants are required to cover a modest portion of the frequency spectrum.

The valve manufacturer is thereby required to spend a great part of his development effort on designing cavities and tuning devices, at the expense of development work on controlling the intrinsic valve parameters. With production concentrated on a minimum number of plug-in valves there are benefits in uniformity of product, reliability and price.

1.2. *Technical Performance*

Many additional and variable factors affecting the performance of the valve are included in an integral cavity and the user can do little about these variations. With an external cavity the user can decide for himself whether to impose strict control on cavity dimensions etc. The changes in characteristics when a valve is replaced are only those due to valve tolerances and do not include a variety of other variables.

If a very wide tuning range is required the problems associated with an integral cavity are almost insurmountable.

1.3. *Flexibility*

The cavity design can be a compromise between tuning range, frequency stability, weight and cost, according to the needs of the particular application. There is also latitude in the choice of resonator shape and type of output coupling or couplings. Design work on many new systems can be started without awaiting development of a new valve which is often required to satisfy some condition which was not appreciated until late in the development.

1.4. *Practical Convenience*

Valve replacement is simplified—an important consideration. This simplification is partly due to the improved electrical tolerances possible because of § 1.1 above, and partly because there is no need to disturb extension shafts which may be coupled to the mechanical tuner. This feature is valuable when motor tuning is used.

1.5. *Replacement Cost*

The cavity is not thrown away when a valve fails.

Many other aspects will be perceived, and since two plug-in valves are now in production this paper has been written with the intention of acquainting the many potential users with their merits.

The two valves give a frequency coverage of 2 to 11 kMc/s or even more if considered as signal sources only. Details of their characteristics are discussed in a later section, together with guiding principles of cavity design and some typical examples. For those readers who are more interested in valve design, some of the problems inherent in the design of a low power reflex klystron are outlined omitting the detailed theory which has been presented elsewhere (Pierce and Shepherd 1947, Hamilton *et al.*, 1948).

An early plug-in valve (Broadway *et al.* 1946) was developed at A.S.E., Bristol during the war. More recently, parallel development has taken place in the U.S.A. (Bohlke and Breeden 1947).

§ 2. The Reflex Klystron

2.1. *General Principles*

It is well known that the reflex klystron operates only in a limited number of conditions of applied voltage known as modes ; for fixed beam voltage and frequency, the power output is an optimum only if the reflector voltage has certain discrete values, corresponding to values of an integer n such that the electronic transit time is $n+\frac{3}{4}$† periods of the oscillation. If the beam voltage, or, more usually, the reflector voltage, is varied around the optimum value, a fine control of frequency is available, covering some tens of megacycles at the frequencies with which we are concerned. This is known as electronic tuning. The frequency range between the half power points, called the electronic tuning range and abbreviated E.T.R., is quite controllable and stable. It is therefore widely used in A.F.C. systems.

The considerations governing the overall design of a plug-in valve are the same as for any other reflex klystron, but with some slight change of emphasis. For example, in order that one valve shall be useful over as wide a frequency range as possible, it is desirable that the variation of reflector voltage with frequency shall be small, and therefore a low beam voltage is advantageous (see eqn. (3)). A plug-in valve is often used in a cavity capable of oscillation in several cavity modes of differing frequencies ; freedom from mode interference (see § 4.1.) is therefore important, and this is most easily obtained with a low order cavity mode. A low gap capacity and high operating voltage favours this condition. Since the valve may have to operate in badly designed cavities it should be affected as little as possible by circuit losses ; this calls for a low beam voltage and high order reflector mode.

Obviously the design must be a compromise between all these conflicting requirements, which tend to be increased in number by the versatility of the valve.

We shall now deal in detail with those properties of greatest interest to the user, some of which are particularly relevant to the plug-in valve. These are :

1. Power output.
2. Electronic tuning range (E.T.R.).
3. Slope of the electronic tuning characteristic between the half-power points.
4. Degree of hysteresis present.
5. Noise power output.

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† For brevity we shall write $N=n+\frac{3}{4}$ in the remainder of this paper.

6. Total useful frequency range.
7. Frequency–reflector voltage law.
8. Effect of varying load impedance.
9. Life.
10. Reproducibility of characteristics from valve to valve.

2.2. *Power Output*

The local oscillator of a modern centimetre-wave receiver using a balanced mixer is not required to give more than 10 mw output. However, other applications may require more, and it is reasonable to ask for as much power as possible above this limit, so long as the power input to the valve is not excessive. The requirement for pre-plumbed systems has led users to ask that the variation of output from valve to valve be kept to a minimum.

For a valve of given design, operating at a fixed voltage, the output power depends mainly on the beam current, and on the value of two coupling factors, viz. between beam and cavity, and between cavity and load. The value of the beam current is determined by the geometry of the electron-gun resonator system provided that the cathode is properly activated and gives uniform electron emission over its surface. Therefore the most important distance is that between gun and resonator ; for the valves to be described, this dimension is controlled to about ±0·002 in. which would cause current variations of about ±2 mA. However, other factors cause the total variation to be somewhat greater than this.

The effective current depends on the cube of the grid interception, and since the coupling of the beam to the circuit also depends mainly on the grids and their spacing, it is important that the grid form should be closely controlled.

The ratio of the load impedance which gives maximum output to that which extinguishes the oscillation is about 2 : 1 (Pierce and Shepherd 1947, p. 478). In the design of integral cavity oscillators it has often proved impossible to avoid large variations in the output coupling, and consequently tight tolerances on load impedance have been necessary to ensure oscillation. Consistent coupling is readily obtained with plug-in cavities, so that this difficulty is much less likely to occur.

2.3. *Electronic Tuning Range*

In modern radar systems the electronic tuning range required is usually only sufficient to compensate for transient changes in transmitter frequency (Ratcliffe 1954), since long term frequency changes are followed by a mechanical tuner. However, it is still necessary to provide sufficient E.T.R. for less sophisticated systems ; this is probably θ·2% of the frequency.

All the factors of valve design which affect the efficiency also affect the electronic tuning range ; these include input voltage and current, cavity losses and electronic mode number ; in addition the shape of the electrostatic field of the reflector is important. A detailed discussion is given elsewhere (Pierce and Shepherd 1947, Pearce and Mayo 1952, Hamilton *et al.* 1948). In general, the E.T.R. is increased by keeping the gap capacity as small as possible, and using a high order electronic mode ; almost all methods of increasing E.T.R. lead to a lower loaded cavity Q. If, however, an attempt is made to carry this too far, frequency stability is reduced (i.e. frequency pulling by the load is greater, and a greater smoothing of power pack supplies is needed), efficiency is reduced, and local oscillator noise is increased.

When the load is varied, the E.T.R. goes through a maximum at the same loading as that giving maximum power ; near maximum power the E.T.R. is thus insensitive to load conditions. The value depends on the cavity (see § 4.1) and can be varied over a wide range in the design.

2.4. *The Electronic Tuning Slope*

The rate of change of frequency with reflector voltage is of considerable interest to designers of A.F.C. systems and low power frequency modulated sources. In both cases the requirement is for minimum variation of slope over the mode and between valves ; the actual value is of secondary importance.

For a plane system, to which practical low voltage tubes approximate, the slope at the centre of the mode is given by (Pierce and Shepherd 1947)

$$\left(\frac{df}{dV_R}\right)_0=\frac{\pi f_0 N}{Q_L(V_B+V_R)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where N is the number of the electronic mode, f_0 the frequency, V_B and V_R the beam and reflector voltage and Q_L the loaded Q of the cavity.

Variations in Q_L, V_B and V_R may give rise to changes in slope. The two former are almost entirely in the hands of the circuit designer, though beam loading (and hence current) may have a small effect on Q_L. The variation of reflector voltage from valve to valve depends largely on valve geometry and is discussed in § 2.8.

Away from mode-centre the slope is given by (Pierce and Shepherd 1947)

$$\frac{df}{dV_R}=\left(\frac{df}{dV_R}\right)_0\left[1+4Q_L{}^2\left(\frac{\delta f}{\delta f_0}\right)^2\right] \quad . \quad . \quad . \quad . \quad (2)$$

where δf is the deviation from the centre frequency. Thus the slope increases as we move away from mode centre, and for a given δf the change is less the lower Q_L. However, for a given valve it is unwise to reduce Q_L much below the value giving maximum power output ; it is better to design the valve in the first place to give optimum output at low Q_L ; here the discussion in the previous section applies.

In practice it is found that the variation over the mode is greater than that caused by changing valves and cavities, provided careful control is maintained over the dimensions of the two latter.

2.5. *Hysteresis*

This phenomenon is well known and will not be described in detail (Pierce and Shepherd 1947). There are two main causes :

1. Multiple transits of a proportion of electrons.
2. Unwanted cavity resonances (Pearce *et al.* 1953).

Electrons making more than the normal two transits of the gap partially retain their bunching and the phase is in general different from that of the main second transit bunches. The effect is greatest when the oscillatory power in the cavity is low, i.e. towards the edge of the mode, and usually the upper frequency side is the more troublesome.

The only satisfactory cure is to prevent more than two transits by controlling the shape of the beam. Two methods of doing this were considered : (*a*) axial metal spikes are attached to both gun and reflector so as to produce a hollow beam which is outwardly diverging over most of its path (Pierce and Shepherd 1947). Such designs are not easy to manufacture, (*b*) the electron optical system is so designed that the beam has a waist in the vicinity of the gap and thereafter spreads out as it goes into the reflector space and back again. It is necessary to make the resonator aperture on the reflector side larger than that on the gun side in order to utilize the returning electrons. This system is used in both CV2346 and VX5048 (an improved version of CV2116) and keeps multiple transits down to an insignificant level.

A similar effect may be observed if the cavity and reflector voltage conditions which give the required frequency are also appropriate to oscillation at some other frequency. This question is discussed in § 4.

2.6. *Noise Power Output*

The local oscillator of a microwave receiver will contribute noise, its magnitude depending on the ratio of the width of the output spectrum of the oscillator to the intermediate frequency. Thus the noise varies inversely with Q_L ; other factors which may affect its value are partition noise, multiple transits, and secondary emission. In most modern receivers local oscillator noise is reduced to negligible proportions by the use of balanced mixers.

2.7. *Total Useful Frequency Range*

One advantage of the plug-in valve is that a wide frequency range can be covered. If this is required in a single cavity it may be necessary to use more than one electronic mode, and in some cases more than one cavity mode.

2.7.1. *Factors Determining the Limits*

At the upper frequency end these are (*a*) a mechanical limit determined by the smallest cavity that can be fitted to the valve ; this is seldom a real limit since the next higher cavity mode can then be used, (*b*) cavity losses increase in proportion to $f^{1/2}$, and, more important, in valves such as the CV2346, designed to operate in a $3\lambda/4$ mode, the dielectric loss becomes excessive at high frequencies, because then, the nodal surface, which at lower frequencies is within the glass, has moved away so that the glass is in a position of appreciable electric field, (*c*) the coupling to the beam falls off with increasing frequency, (*d*) when the electronic mode number is increased the valve efficiency falls, and when the cavity mode number is raised the cavity losses increase.

The lower frequency limit is determined by the reflector voltage. For a given electronic mode the reflector voltage decreases with frequency until the fastest electrons strike the reflector which then ceases to function normally. The minimum safe voltage is about 70 volts at the low voltage side of the mode. To operate at lower frequencies the next mode must then be used, but after the mode giving greatest efficiency is passed the performance deteriorates and in the lowest mode the valve may not oscillate.

2.8. *The Frequency–Reflector Voltage Law*

This relationship is of interest when the reflector voltage is ganged with the mechanical tuner. Fortunately the reflex klystron gives a good approximation to a linear law ; under reasonable assumptions it may be shown that the optimum reflector voltage is given by the equation :

$$V_B+V_R=\frac{LfV_B{}^{1/2}}{5{\cdot}91N(1-E)} \qquad \ldots\ldots \qquad (3)$$

where

$$E=\frac{gf}{23{\cdot}6NV_B{}^{1/2}} \qquad \ldots\ldots \qquad (4)$$

L=resonator–reflector distance and g the resonator gap including grid thickness, in inches, and the frequency f is in Mc/s. The factor E takes account of the finite transit time of the electrons between the control grids, and is generally small. Over the greater part of the frequency ranges of the valves which we shall describe, E is about 0·1 so that its frequency dependence may be neglected, and the relationship between V_R and f is sensibly linear. Even at the highest frequencies the curvature is so slight that over a 15% frequency band a linear law will give V_R within a few volts of the optimum voltage for a particular valve.

Variations of L and g will produce differences in the constants of this linear equation, and by differentiation of (3) it may be shown that

$$\frac{\partial V_R}{\partial L}=\frac{V_B+V_R}{L}$$

and

$$\frac{\partial V_R}{\partial g}=\frac{V_B+V_R}{4V_B}\cdot\frac{\partial V_R}{\partial L}$$

For example, in the CV2346 $\partial V_R/\partial L$ and $\partial V_R/\partial g$ are about 7 and 3 volts per 0·001 in. respectively ; in practice a spread as low as ±0·001 in.

to ±0·002 in. has been achieved, so variations in V_R of up to ±20 volts may be expected. Since this variation is comparable with the width of the mode (about 30 volts between half-power points), a pre-set adjustment of V_R is required to allow for variations between valves ; however, since the range of adjustment required is not large, the chance of serious misalignment should be small.

2.9. *Frequency in a Given Cavity*

There is some advantage in designing a valve to give as high a frequency as possible in a cavity of a given size. More important, however, is the variation of frequency when different valves are plugged into a given cavity.

In the manufacture of plug-in valves the gap capacity of each valve is set before processing, by clamping it in a cavity and adjusting the gap for resonance at a predetermined frequency. Even so, variations of frequency in the final valve occur, mainly because (*a*) small distortions take place during processing, and (*b*) owing to small variations in shape of the copper diaphragms all valves do not have the same inductance to capacity ratio, so that even if identically tuned in one cavity they may show deviations at other frequencies.

2.10. *Summary Concerning Reproducibility*

It is evident that the physical dimensions most in need of control are the reflector spacing, the resonator gap, the thickness of the grids in an axial direction, the gun spacing, and some dimensions within the gun (Pearce 1952). Uniform cathode activity, which depends upon the treatment of the parts of the valve, before and during manufacture, is also important. A number of other factors which have to be kept under control have not been mentioned. One such is the correct alignment of the electrodes with respect to the cavity ; if this is faulty the general performance of the tube is poor.

§ 3. PRACTICAL DESIGNS

3.1. *General*

This paper is concerned principally with two valves which are well established. The CV2116 (VX5029) was designed for the S-band and the CV2346 (VX5028) for the X-band (Pearce *et al.* 1951, Pearce *et al.* 1953. Pearce 1952), but as will be shown later, both valves have a useful performance over a wide band. Concerning a third valve of the plug-in type, the VX5048, nothing more than brief mention can at this time be given since manufacture has not yet commenced and slight changes may yet occur (Taylor 1956). It is an S-band valve and is an improvement on the CV2116 in the following particulars.

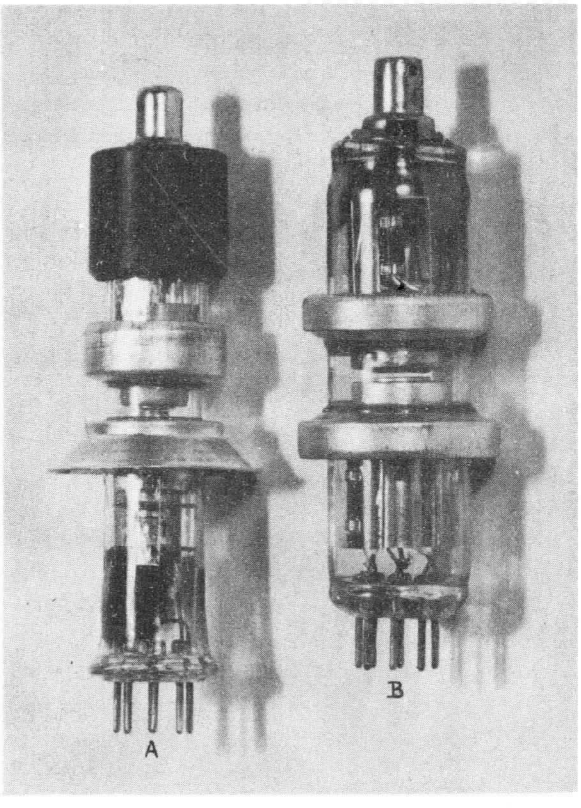
1. Hysteresis is virtually absent.
2. The upper frequency limit in a fundamental cavity has been raised to about 4·2 kMc/s.

In appearance and size it is somewhat similar to CV2116 except that the lower diaphragm is conical.

3.2. *CV*2346

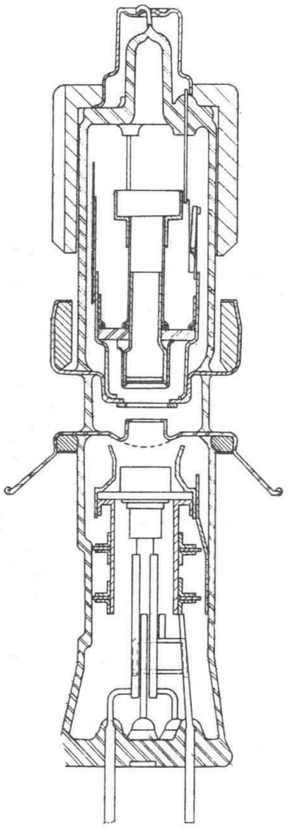
A general view of the valve is given in the photograph (fig. 1 (A)) and a scaled sectional view in fig. 2. The envelope is of lead glass to which the copper diaphragms are sealed. The upper diaphragm is of cylindrical shape on the outside and necessitates a spring contact in the cavity. The lower diaphragm has a conical shape. It fits into a conical recess in the cavity and is clamped by means of an external conical shaped flange.

Fig. 1



Plug-in reflex klystrons.
A. CV2346 for 3–11 kMc/s.
B. CV2116 for 0·5–5 kMc/s.

Fig. 2



Sectional view of plug-in reflex klystron CV2346.

This arrangement provides a reliable contact. eliminates the need for a spring at this diaphragm, and ensures accurate location of the valve in the cavity.

The bakelite cap at the reflector end of the tube has a longitudinal slot. This may be used as a keyway to engage a pin mounted on the cavity so that the valve is always inserted with the same orientation.

The electron gun is of the Pierce type and has a flat oxide cathode of 5·4 mm diameter mounted on a ceramic spacer inside a focusing electrode which is flared outwards at its end. Across the anode aperture of the resonator, facing the cathode, a curved tungsten gauze is fitted to act as accelerator.

The 'honeycomb' grids covering the resonator apertures (of diameters 3·0 mm and 4·0 mm for the gun and reflector ends respectively) are made of copper. In the direction facing the cathode the copper thickness is only 0·0005 in. so as to minimize electron interception, but good heat conduction and rigidity are ensured by having a longer dimension in the axial direction—it varies from 0·005 in. on the axis to 0·010 in. at the edge of the apertures. A single grid of this sort has been found capable of dissipating at least 30 watts before glowing dull red. The diameter of the cell is approximately 0·017 in. and the distance between grids is about 0·012 in.

Grids of this sort can be made flat, and remain reasonably flat in operation ; this helps in achieving reproducible reflector spacings. Such grids are also robust and withstand vibration.

The reflector is essentially a shallow dish about 4 mm diameter and 0·5 mm deep and is mounted on a ceramic washer which abuts against a shoulder in a nickel tube. The latter is pushed home into the cylindrical boss of the resonator diaphragm. By paying close attention to the accuracy of the important dimensions, the reflector spacing can by this means be controlled to within ±0·001 in. to 0·002 in.

The gun is held central by means of mica washers which are a good fit in dimples pressed into the glass. The gun to resonator spacing is set by microscope before sealing in.

The dimensions of the valve are chosen for operation in a $3\lambda/4$ cavity mode and the glass between the diaphragms is near a nodal surface at mid-band frequency.

3.3. *CV*2116

As will be seen from fig. 1 (B), this valve is broadly similar to the previous one, so a detailed description will not be given. The differences are mainly due to the fact that the CV2346 was not finalized until several years after the CV2116 and further development had taken place in the interval.

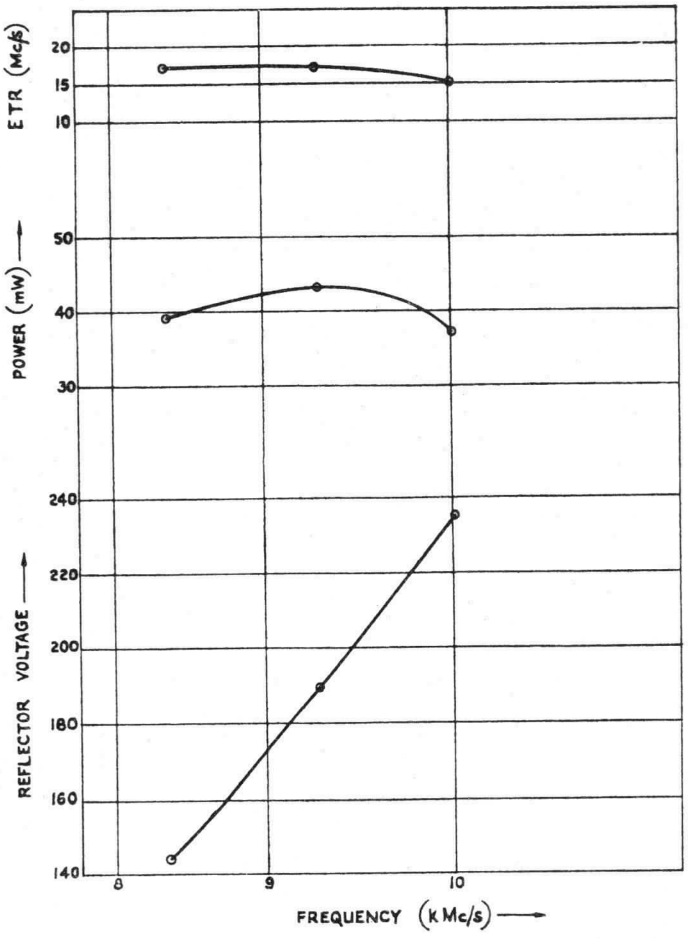
The principal differences are : (1) the resonator diaphragms are of cylindrical shape at both ends, so that two spring contacts are usually necessary, (2) the electron gun is not of the Pierce type but has a cathode of 6 mm diameter producing an electron beam which converges only slowly as it approaches the resonator. The resonator apertures are about 7·5 mm diameter. This arrangement leads to a certain amount of multiple transit hysteresis, (3) the resonator grids are made in a different way. Thin copper tape of section 0·020 in. × 0·002 in. is silver plated, crinkled, wound into a flat spiral and brazed into the resonator diaphragm. This is not as controllable as the later honeycomb type, (4) the usual cavity mode employed is the fundamental.

3.4. *Characteristics of CV2346*

3.4.1. *Power Output, E.T.R., and Reflector Voltage*

Figure 3 shows the average results obtained in the three standard test cavities in the normal test band (8·5 to 10 kMc/s) on a run of 80 valves.

Fig. 3

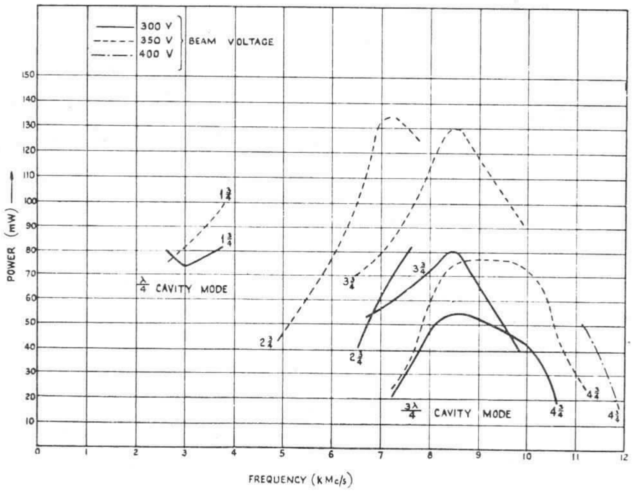


Average performance of 80 valves using $4\frac{3}{4}$ electronic mode in $3\lambda/4$ cavity at a beam voltage of 300 volts.

The input voltage was 300 volts and the electronic mode $4\frac{3}{4}$ periods, which is best for these frequencies. The power output is seen to be reasonably flat over this band. For reasons of convenience in testing the normal test band was restricted to that principally in use, but the tests carried out within this band are sufficiently stringent to assure satisfactory operation at other frequencies.

Over a wider band, measurements of power output in radial line cavities of different diameters are given in fig. 4. These results are the average of a small number of valves from a later batch. The difficulty of making satisfactory measurements over such a wide frequency range will be appreciated, and fig. 4 should be regarded as a qualitative picture of the behaviour of the valve, modified to some extent by measurement conditions.

Fig. 4



Power output of CV2346 in radial line cavities.

It will be seen that a useful output is obtained over a frequency range of about 5 to 12 kMc/s in a $3\lambda/4$ cavity mode and, in addition, frequencies around 3 kMc/s may be obtained in a $\lambda/4$ cavity mode. At frequencies approaching 12 kMc/s, it is necessary to increase the input voltage to 400, which is safe for short periods provided the valve is well cooled. For frequencies below 8 kMc/s, the $4\frac{3}{4}$ electronic mode becomes inefficient because the reflector voltage is decreasing, and lower order electronic modes are preferable. At almost all frequencies, appreciably more output is obtained with a beam voltage of 350 volts than with 300 volts.

The electronic tuning ranges associated with these modes are given in Table 1 over as wide a frequency range as permitted by the wavemeters available. No wide variation with frequency is observed.

For some purposes, an E.T.R. of 30 Mc/s or more is desirable. This has been achieved by modifying the cavity so as to have a capacity rim at the appropriate place†. This is usually close to the glass so in practice the rim is attached to one diaphragm of the valve. With this arrangement the mechanical tuning is somewhat restricted.

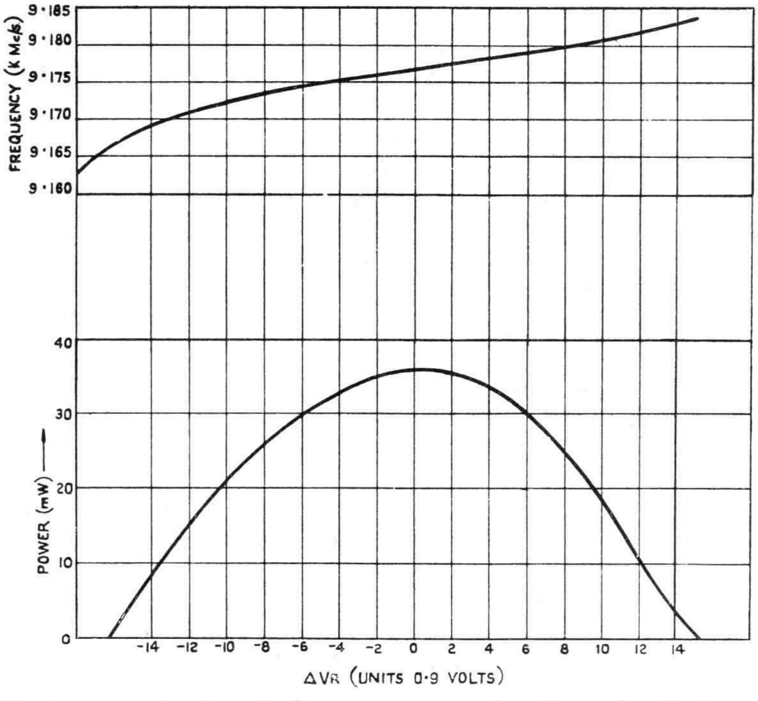
Table 1

Frequency (kMc/s)	7	8	9	10
E.T.R. (Mc/s) $4\frac{3}{4}$ Mode 300 Volts	—	16	16	13
E.T.R. (Mc/s) $4\frac{3}{4}$ Mode 350 Volts	—	21	22	20
E.T.R. (Mc/s) $3\frac{3}{4}$ Mode 300 Volts	10	10	9	8
E.T.R. (Mc/s) $3\frac{3}{4}$ Mode 350 Volts	11	13	12	11

3.4.2. *Shape of Mode*

A typical curve of power output and frequency as a function of reflector voltage for the usual $4\frac{3}{4}$ mode is shown in fig. 5. Some asymmetry is noticeable, but not prominent.

Fig. 5



CV2346 power output and frequency as a function of reflector voltage for the $4\frac{3}{4}$ electronic mode.

3.4.3 *Noise Output*

The average excess noise temperature ratio of a few valves has been found to be 0·53. For this test, an image matched mixer was used and the conditions were : intermediate frequency 45 Mc/s, conversion loss of

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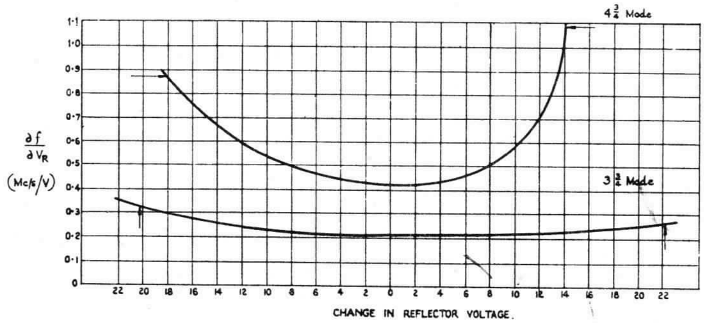
† B.P. 14,634/1954.

crystal mixer 6 dB, oscillator power 1 mw. An excess n.t.r. of this value corresponds to a worsening of the signal to noise ratio of the receiver, from 9 dB to 10 dB. Where this might be disadvantageous, a balanced mixer is used.

3.4.4. *Slope Measurements*

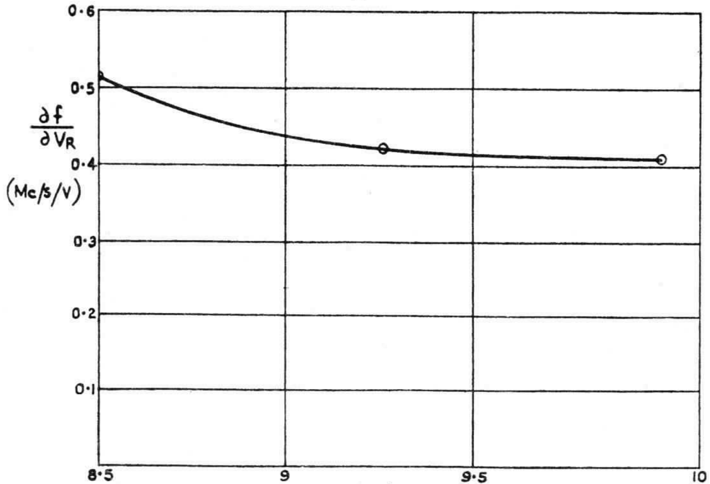
Figure 6 shows the way in which the slope of the reflector characteristic, df/dV_R, varies over the mode for two electronic modes. The half power points are indicated. Some asymmetry, particularly in the $4\frac{3}{4}$ mode, is noticeable. This is a direct consequence of the asymmetrical power output curve of fig. 5.

Fig. 6



CV2346 electronic tuning rate at 9·3 kMc/s. (Half power points indicated by arrows.)

Fig. 7



CV2346. Slope (df/dV_R) at the mode centre.

Figure 7 shows how the slope at the centre of the mode varies over the frequency range 8·5 to 10 kMc/s. The increase at 8·5 kMc/s is mainly due to a decrease of Q_L.

3.4.5. *Reproducibility of Characteristics*

Table 2 gives statistical results for reflector voltage, frequency, input current, output power, and slope, for a number of tubes when plugged into the same test cavity. Columns 3 and 4 show the limits within which 50% and 90% of the tubes would lie, respectively. For instance, 90% of the tubes have an optimum reflector voltage falling between the limits 173 and 205 volts. If we assume that this variation is due solely to change of reflector spacing, the reflector spacing limits are about ±0·002 in. Since, in fact, other factors contribute, the actual variation would be rather less. This variation is small because of the method used to locate the reflector; if it were necessary to control the reflector voltage to finer limits, special methods of mounting the reflector would be necessary.

Table 2. CV2346 Reproducibility. (Results on 80 pre-production valves)

	Mean	Std. dev. σ	$0{\cdot}67\sigma$	$1{\cdot}61\sigma$
V_R	189	9·7	±6·5	±15·6
f	9276	20·3	13·6	32·7
i	30·0	3·4	2·3	5·5
Power	43·3	6·6	4·4	10·6
$\left(\frac{df}{dV_R}\right)_0$	0·42	0·05	0·033	0·080

50% of valves lie within $\pm 0{\cdot}67\sigma$
90% of valves lie within $\pm 1{\cdot}61\sigma$

3.5. *Characteristics of CV*2116

3.5.1. *Power Output and E.T.R.*

Over the range 2·6 to 3·6 kMc/s, using the fundamental cavity mode and the $2\frac{3}{4}$ electronic mode, the power output is almost constant and is in the region 150 to 220 mw. The E.T.R. too is reasonably flat over this range and is in the region 20 to 25 Mc/s. At a frequency of 3·75 kMc/s using the same electronic mode but a $3\lambda/4$ cavity mode, the E.T.R. is about 10 Mc/s.

Oscillations have, however, been obtained over a much wider band from 0·5 to 5 kMc/s (Ratcliffe 1952), but the power was not seriously investigated. In another investigation (Smith 1953), a useful output was obtained over the frequency range 2·38 to 5 kMc/s using a coaxial line cavity with slot output, without any coupling adjustment. The results are given in table 3. The power output at the extremes of this band, could, undoubtedly, have been considerably improved by an adjustment of the coupling.

The usual input conditions for this valve are 250 volts 25 mA.

3.5.2. *Reproducibility of Characteristics*

Since the spacings are greater in this valve, reproducibility is easier to achieve, though the presence of hysteresis in random degree militates against this. The results obtained on a batch of 56 production valves at 3·2 kMc/s are shown in table 4.

Table 3

f (kMc/s)	2·38	2·72	2·88	3·09	3·33	3·41	3·70	4·06	4·40	5·00
Output (mw)	25	80	120	152	160	180	190	80	60	20
V_R (Volts)	87	115	138	160	192	205	255	142	210	78
Mode	—	—	—	$2\frac{3}{4}$	—	—	—	$3\frac{3}{4}$	—	$4\frac{3}{4}$

Table 4

Characteristic	V_R	I(mA)	E.T.R.	Mean slope df/dV_R between half power points
Mean	180	27·9	23·8	0·80
Std. dev.	5·1	2·8	2·4	0·06

Table 5

Valve	Cathode voltage	Heater voltage	Number tested	Life (hours)		
				Average	Maximum	Minimum
CV2346	300	6·3	43	2800	4800	760
	300	5·8	7	5200	8100	2150
	300	5·0	5	Still good at	8000	
	350	6·3	24	2250	5800	16
CV2116	250	6·3	11	8 still good at	2400 —5000	2350
	325	6·3	6	1850	3300	650

3.6. *Life*

Table 5 shows the results of life tests on the two types under various conditions. Tests on CV2116 at a heater voltage of 5·8 showed a life of at least 10 000 hours.

3.7. *Ruggedness*

Neither of these valves was designed with ruggedness specifically in mind, and on the CV2116, no tests have been made. A number of tests have been carried out on the CV2346 and the behaviour under conditions either of intense vibration or impact seems to be very good for a valve of this type.

3.8. *Frequency Stability*

The frequency stability of both valves is very good, given stable voltages. The average warming-up drift of the CV2116 in a $\lambda/4$ cavity is about 750 kc/s at 2·65 kMc/s, while the temperature coefficient of the CV2346 averages —40 kc/s per °c, the coefficient of the cavity being additional to this.

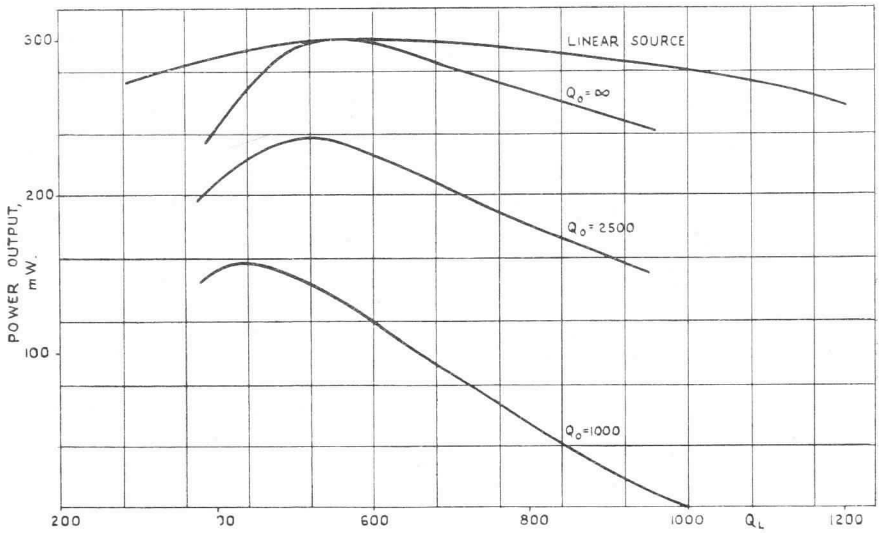
§ 4. Cavity Design

Since the design information cannot be condensed into simple exact rules it is proposed to discuss the possibilities very broadly, to give some precise information about certain essentials, and to illustrate with selected examples.

4.1. *General*

So far as the user is concerned the reflex klystron may be considered as a non-linear negative conductance element or two-terminal generator possessing certain special features which have been described in § 2.

Fig. 8



Variation of output power of CV2116 with loaded and unloaded Q. (Coaxial $3\lambda/4$ cavity. 3·7 kMc/s.)

The non-linear property is exemplified by the variation of power output with load (fig. 8), particularly the manner in which the power output falls rapidly to zero at a critical loading.

In principle, any type of transmission line could be attached to the valve, to form a resonant circuit. However, development has been chiefly confined to two types—radial line and coaxial line—and it is suggested that these basic types will suffice for the majority of applications.

With each type of cavity there is a choice of tuning methods and load coupling. Tuning may be achieved by physical change of the main resonant element, or electrically using a change of dielectric. Both methods, especially the former, are used where wide frequency bands have to be covered. For narrow band tuning, say, less than 1%, some form of trimmer may be employed.

Whatever form of tuning is adopted, the wider the frequency cover the more difficult it is to design the load coupling, or to set it if the coupling is made adjustable. For the majority of requirements the load coupling should be designed so that no adjustment with change of frequency is required and it is therefore important to avoid using a tuning system which causes gross distortion of the field in the resonator.

With elementary types of cavity, i.e. those approximating to a $(2k+1)\lambda/4$ line, the admittance change with frequency is similar in form to that of a simple lossy L.C. circuit. The electronic tuning rate and power output will vary over the mode (see figs. 5 and 6) and, if it is desired to use the valves as a frequency-modulated source, the modulation depth is limited to a small fraction of the mode width. The frequency width of the mode is roughly inversely proportional to $(2k+1)$ so that a $\lambda/4$ line is best for this purpose and the linear portion of the mode is increased as the loading is increased. By using a complex circuit with two tuned elements properly coupled it is possible to achieve more suitable characteristics (Reed 1953).

For the most common applications the guiding rules in choice of cavity are :

(*a*) Choose a symmetrical type.

(*b*) Use the simplest approximation to a $(2k+1)\lambda/4$ resonant line, and the lowest convenient value for k.

(*c*) Use the simplest form of tuner consistent with setting accuracy requirements.

Both the radial and coaxial line cavities give a symmetrical coupling of the resonant element to the electron beam. With both types there is a choice of dimensions controlling the characteristic impedance of the line, and this in turn affects the cavity losses and the corrections in resonant length caused by the discontinuity at the valve electrodes. The most serious factor to contend with is the possibility of obtaining oscillation at more than one frequency. For example, the desired operation may be in a $\lambda/4$ cavity resonance with a reflector mode of $1\frac{3}{4}$ cycles, and the cavity may have a $3\lambda/4$ resonance at a higher frequency such that the reflector voltage is suitable for the $4\frac{3}{4}$ cycle mode. Such coincidences are unusual, but can be very serious in effect and at the least will cause some discontinuity in the electronic tuning characteristic. The interferences may be moved by changing cavity dimensions or sometimes a change in resonator voltage may be sufficient to remove a discontinuity outside the required frequency range. Another method is to eliminate the unwanted mode by the use of a mode suppressor†. It is always worth while plotting the various modes of oscillation over the range of the tuner to check whether there is any tendency for an interference to occur.

The coaxial line resonator is the most versatile, and is particularly suitable when a wide frequency cover is required because the resonant length can be changed by moving a single shorting plunger. The radial line cavity is less suitable for wide tuning ranges, but a simple design covering up to 20% is described in § 4.2.

Some padding is normally desirable between the valve and the load (usually a crystal mixer) but even so, most valve designs have power in hand. If power output alone is taken as the criterion of cavity performance it may not seem important to reduce the cavity losses, although fig. 8 shows that losses, as measured by Q_0, do have significant effect. However, unless the losses are controlled difficulties may arise through their variation, and furthermore there is the danger that the loading condition chosen may be unsatisfactory. Excessive cavity losses are most frequently caused by poor contacts to the valve, poor joints in the cavity, or lossy tuning devices, and can easily be kept to reasonable proportions.

The output coupling is usually one which is predominantly coupled either to the electric or the magnetic field, e.g. by a probe or loop. With waveguide systems a coupling through a slot in the cavity wall is usually preferred because it is more easily defined in physical dimensions. The power output and electronic tuning range are not critically dependent on loading around the optimum value, but the electronic tuning rate is inversely proportional to the loaded Q of the cavity. The load coupling must therefore be designed to maintain a reasonably constant Q value over the frequency band if the electronic tuning rate is an important parameter. With a fixed coupling it is difficult to obtain satisfactory results over more than a 25% band of frequency, because the standing wave pattern of the field changes except close to the valve or shorting plunger, and neither of these positions is practical. A combination of coupling to the electric and magnetic fields, or a distributed coupling such as a directive feed, can be used over a wide frequency band. For this reason attempts have been made to develop cavities using rectangular waveguide as the main resonant element, but with this type of cavity two tuning plungers are required for a wide range (Spencer 1955).

4.2. *Some Practical Details*

When designing a cavity it is desirable to produce some form of plot relating frequency, tuner position and reflector voltage for both the wanted mode and any others which may occur within the tuner and reflector voltage ranges required. From this the possibility of interference

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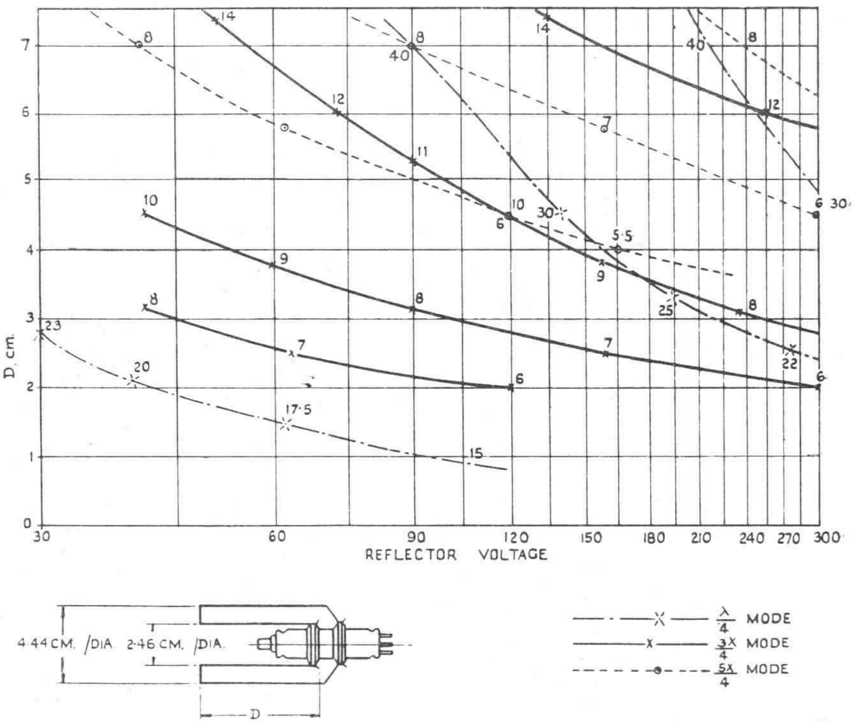
† A practical suppressor has been designed by W. E. Boud and L. T. King (see B.P. 751, 741).

and measures necessary to avoid it may readily be assessed. Figures 9 and 10 are examples of such plots, though they are both far more comprehensive than would be required for a cavity of any but the widest range. Figure 9 is for the CV2116 in a coaxial cavity of the dimensions shown, where optimum reflector voltage for oscillation is plotted against

Fig. 9

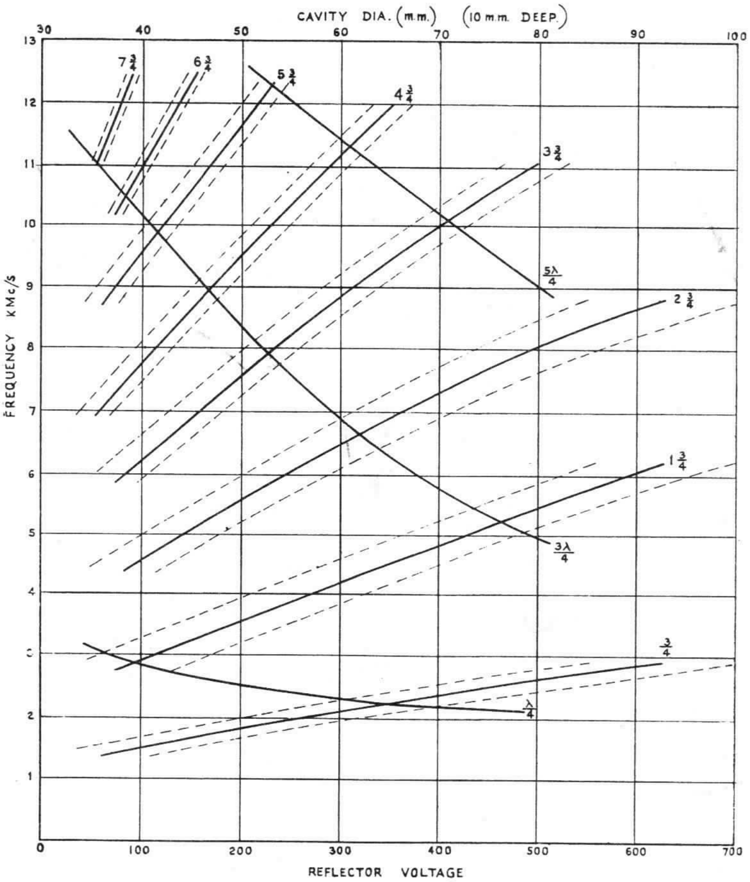


Mode chart for CV2116 in coaxial cavity. (Figures on curves indicate wavelength in cm.)

tuner position, the figures on the curves indicating wavelength of oscillation and the reflector and cavity modes. Interference may occur where two lines cross, or nearly cross. This type of plot becomes very complex if it is desired to indicate the finite widths of the modes. Figure 10 is a chart for the CV2346 in a radial line cavity of height 10·0 mm. Here the lines sloping up from left to right are of reflector voltage at mode centre (full) and mode edges (dotted) against frequency, while the curves sloping down from left to right are of cavity diameter against frequency. Possible interferences are not so obvious but can readily be detected ; for example, at 10·5 kMc/s using the $3\lambda/4$, $5\frac{3}{4}$ mode, interference with the $\lambda/4$, $1\frac{3}{4}$ mode at about 2·9 kMc/s would be likely but this could be avoided simply by using the $4\frac{3}{4}$ mode. Although the cavity dimensions shown may not be the most suitable for all applications, the range of values is limited by the valve dimensions and the desirability of using an outer dimension which is small enough to avoid undesirable waveguide modes and yet not so small that the circuit losses are serious.

In practice the resonant frequency may be significantly altered by the load coupling, but it is usually possible to design a form of coupling which does not add susceptance. Sometimes susceptance may be added deliberately to affect one type of resonance more than another and thereby remove an interference.

Fig. 10



Mode chart for CV2346 in radial line cavity of height 10 mm.

The design and manufacture of suitable contacts between the valve and cavity seems to present a difficulty to some users. However, it has been proved possible to make cavities which will give consistently good results for many thousands of insertions and after long exposure to humid conditions.

Contacts for the CV2116 are the more difficult. It is possible to make contact to the larger copper of this valve by clamping down on the small flat annular surface but this type of contact is not satisfactory in the region of 3·7 kMc/s where there is a current maximum close to the contact. The spring contact to the smaller diameter copper must be capable of distortion sufficient to take the tolerances on diameter and eccentricity if the large copper is clamped. The location of the valve in the cavity may be defined by a shoulder stop for either copper. Various designs of spring have been used, but those shown in fig. 15 have been proved most reliable. The contact to the larger copper is made by winding beryllium copper strip 0·004 in. by 0·10 in. into a close wound spiral, the ends of which are soldered together to form a ring, which is compressed after insertion of the valve. Spring finger contacts of beryllium copper are used for the inner contact of the coaxial line with equal success.

The experience gained with CV2116 led to a redesign of the valve coppers in CV2346. The conical skirt fitted in place of the larger diameter ring has been found very satisfactory, both in respect of good electrical contact and reproducible location. The valve dimensions are checked in a test gauge with only 1° taper between the different cones to minimize wear on the valve copper, but in normal use the same valve would not be inserted many times and a larger taper may be used to give even greater certainty of a good contact. The locating spigot of bakelite on the CV2346 was fitted primarily to reduce the frequency tolerance which would otherwise need to include effects of random orientation, and also to prevent wear of spring fingers caused by rotating the valve. This spigot has been toleranced to centre the valve with sufficient accuracy on insertion, and prior to engaging any spring contacts, so that fouling of spring fingers can be prevented. Long beryllium copper spring fingers have been used to form a $\lambda/2$ low impedance line, and this type of contact has proved successful for a 30% frequency band. The dimensions have been chosen so that the spring is approximately cylindrical when a valve is inserted and a cylinder inside the fingers dimensioned so that only a small displacement of the fingers occurs on inserting a valve. This type of spring requires a force of about 3 pounds to insert the valve and contact losses are small in the region 8·5 to 10 kMc/s. In the region of 5 kMc/s the contact will be close to a current maximum and experience with the CV2116 at 3·7 kMc/s showed that a pressure of 2 pounds per finger (16 fingers) was necessary to make sure that contact resistance was undetectable. Spring fingers which are burred or distorted so that the length of line contact is reduced may give contact troubles. With well-made contacts for the CV2346 it is possible to wobble the valve in its seating within limits imposed by the clearance round the spigot without any significant effect. If the circuit is to be exposed to shock or vibration it is as well to take the further precaution of locking the valve by a wedge at the spigot end to reduce the strain imposed on the glass-to-metal seals.

Most tunable cavities, except those for small ranges where a trimmer may be used, require a movable short circuit, the shape of which depends on the type of cavity. Non-contacting choke systems are preferable as a means of maintaining a negligibly small impedance between the fixed and moving members. The theoretical requirements have been treated extensively by Huggins (1947) and the essential feature required is a line of very low characteristic impedance. Because of the very small clearances required (0·010 in. or less) and the need to avoid any stray contacts along the length of the choke section, the mechanical tolerances are critical and the surfaces must be smooth. Very small clearances may be used with a choke made of anodized aluminium and the low impedance thereby obtained makes the choke suitable for a wide range. However, experience with such devices has shown that many types of anodized surface are lossy and results may be very unsatisfactory if the materials and processing are not carefully controlled.

Table 6

Valve	Cavity	Reflector mode	Loaded Q	Unloaded Q
CV2116	$\lambda/4$ radial 2·6–3·2 kMc/s	$2\frac{3}{4}$	100–150	600–1000
CV2116	$3\lambda/4$ coaxial 2·7 kMc/s	$2\frac{3}{4}$	350	1500–2000
CV2116	3·7 kMc/s	$2\frac{3}{4}$	650	1500–2500
CV2346	$3\lambda/4$ radial 8·5 kMc/s 9·35 kMc/s 10 kMc/s	$4\frac{3}{4}$	700 700 850	1500–2000

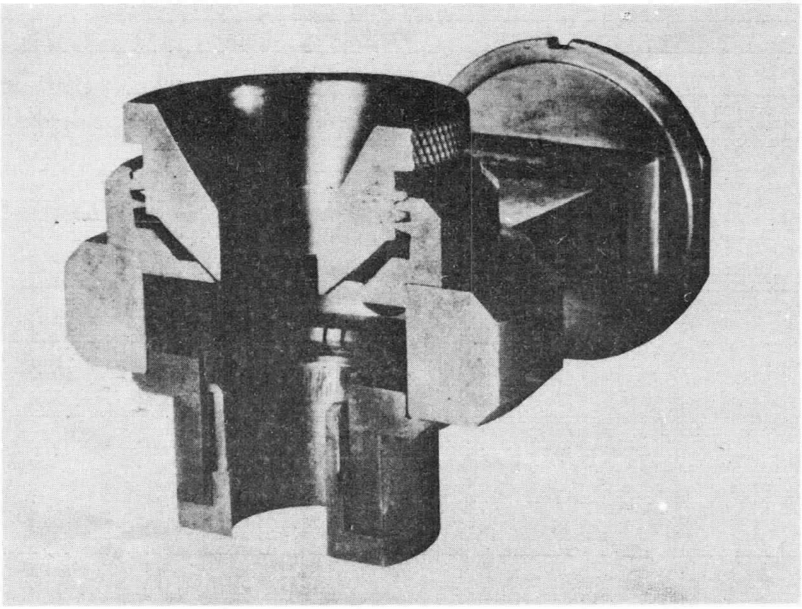
During development it is advisable to measure the cavity losses, and the unloaded Q value with a cold valve inserted is a suitable parameter since this will also indicate any defects in the contacts to the valve, although some of the loading will also be due to losses in the valve grids and glass. Q values may be calculated from results of standing wave-measurements (Altar 1947), or, in special circumstances, transmission filter measurements may be made. Tolerances on these valves are so close that it is seldom necessary to select ‘ average ’ valves for circuit development unless the requirements are particularly critical.

To assist designers, table 6 gives some values for loaded and unloaded Q which are representative of good practice.

4.3. *Practical Cavities*

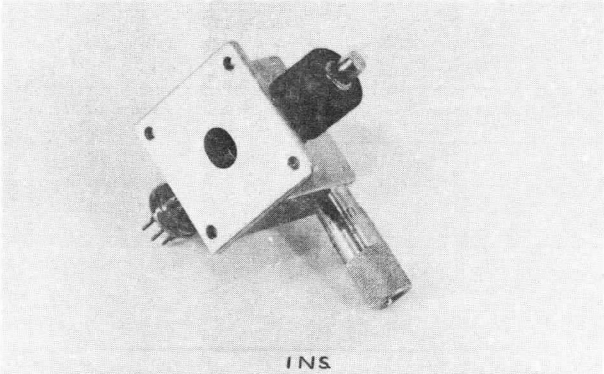
Figure 11 shows a sectional view of a simple fixed frequency cavity for the CV2346, similar in form to those used for testing the valve. The variation of frequency with diameter of such a cavity is shown in fig. 10, though this was obtained using a simpler spring contact ; the $\lambda/2$ spring fingers give a frequency 50 to 100 Mc/s greater for the same diameter. By coincidence the curve shown for the $\lambda/4$ mode in fig. 10 is almost identical with that for a CV2116 cavity of height 0·79 cm.

Fig. 11



Sectional view of fixed frequency cavity for the CV2346.

Fig. 12

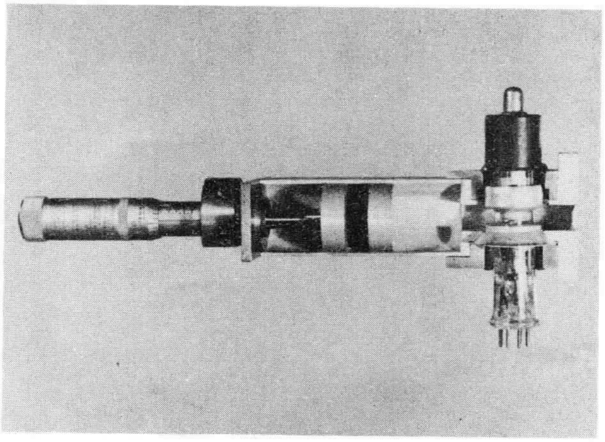


Cavity for CV2346 with Frequentite tuner. (Tuning range 300 Mc/s approx.)

Such cavities, with the addition of simple trimmers, can readily be used to provide oscillators of limited tuning range. Figures 12 and 13 show photographs of two examples ; the former a CV2346 cavity tuned by a Frequentite rod of 0·26 cm diameter traversing a chord, and giving a tuning range of about 300 Mc/s ; the latter a sectioned cavity which was tuned by an anodized piston in a length of circular waveguide coupled to the radial line, giving a tuning range of about 600 Mc/s.

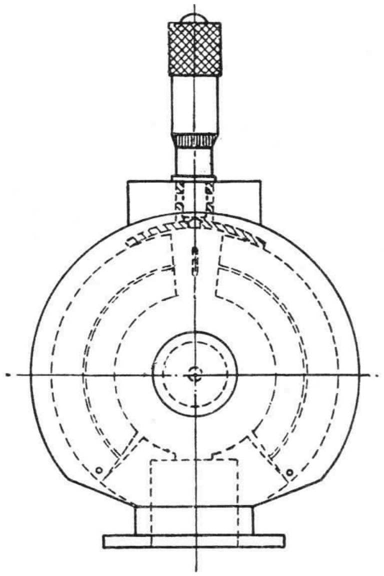
A radial line cavity giving a tuning range of up to 20% is illustrated in fig. 14 ; in this case the diameter is effectively varied by moving two

Fig. 13



Cavity for CV2346 with anodized piston tuner. (Tuning range 600 Mc/s approx.)

Fig. 14

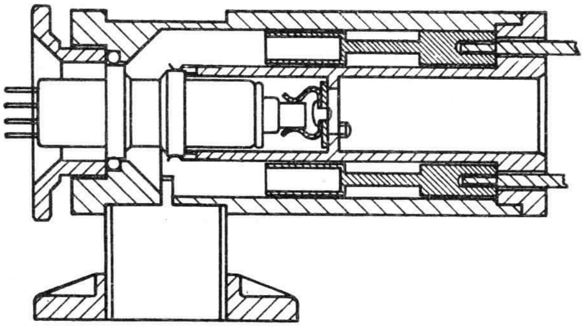


Cavity for CV2346 with variable diameter tuner. (Tuning range up to 20%.)

C-shaped side members which are spaced off the top and bottom of the cavity and have chokes cut into them on both sides†.

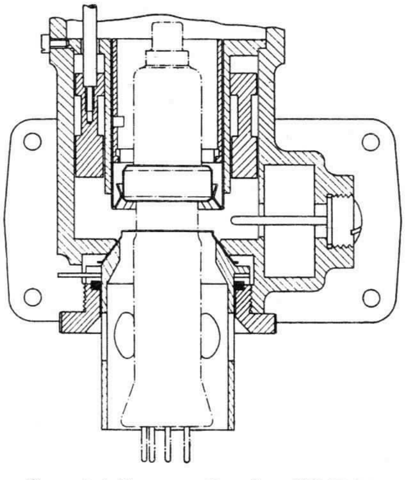
A coaxial line cavity for the CV2116 is shown in fig. 15 ; it was designed to tune over the range 3·1 to 4·2 kMc/s, but with a modification to allow greater travel of the tuning mechanism gave the results shown in table 3.

Fig. 15



Coaxial line cavity for CV2116.

Fig. 16



Coaxial line cavity for CV2346.

It is of particular interest in that it operates successfully despite many possible sources of trouble. Reference to fig. 9 shows that when using the 3λ/4, 2¾ modes in this region, interference from both λ/4 and 5λ/4 modes is possible, and both were encountered during the development.

---

† These cavities, designed by L. T. King, are available for the following frequency bands :

$$\left.\begin{array}{l}6{\cdot}5\text{–}7{\cdot}5\ \text{kMc/s}\\ 7{\cdot}5\text{–}8{\cdot}5\ \text{kMc/s}\\ 8{\cdot}5\text{–}10\ \ \text{kMc/s}\end{array}\right\}\ \text{for CV2346.}\quad 2{\cdot}7\text{–}3{\cdot}4\ \text{kMc/s for CV2116.}$$

The reactance of the output coupling slot was used to move the wanted mode away from the $\lambda/4$ mode, while the $5\lambda/4$ mode was overloaded by placing the output slot at the current maximum of this mode, so setting up the required $3\lambda/4$ mode preferentially. Some difficulty was experienced with the TE_{10} waveguide mode ; the choke tuning plunger then in use was shown to provide a coupling between this and the coaxial mode. The ' bucket ' type plunger shown was found to eliminate this and also gave lower losses than any other tuning plunger tried ; the plunger is held 0·010 in. off the cavity walls by small nylon studs.

Figure 16 shows a coaxial cavity for the CV2346 which tunes over the range 8·5–10 kMc/s. The main body of the cavity is of die cast aluminium and all aluminium parts are anodized, so providing both resistance to corrosion and insulation between cavity and tuning plunger. This cavity was designed in the Stanmore Laboratories of the G.E.C. to whom we are indebted for permission to publish this description.

§ 5. CONCLUSIONS

Experience with the valves described in the hands of many different users has proved that the advantages expected of the plug-in valve have been achieved without any serious attendant disadvantages. Even the protagonists of the valves have been surprised by the consistency of characteristics achieved, and the versatility as demonstrated by the range of uses to which they have been put, as for example in the use of high order cavity modes to provide frequency stability or low noise output, and in the cavities of very wide tuning range which have been designed.

It has been proved that cavity design really involves no greater problems than the design of lumped circuits, though the process tends to be slower since machining is generally involved in circuit modifications.

There will probably always be some users requiring wide electronic tuning ranges and others who insist on much less. This can partly be dealt with by cavity design, and in addition the use of the capacity rim has provided a very neat method of extending the range available without multiplying the number of basic valve types to be produced. For users whose requirements are better suited by a valve with a simple cavity attached it is not difficult to solder the valve into such a cavity and supply it in this way.

Apart from the improvements expected from VX5048, and detail development of such qualities as ruggedness, it is difficult to envisage further advances being required or possible with the reflex klystron type of valve. There is reason to hope therefore that the valves described will be accepted as standard tools of the microwave designer for many years to come.

ACKNOWLEDGMENTS

The authors are indebted to the Amiralty and the Ministry of Supply, and to Messrs. Electric and Musical Industries Ltd., for permission to publish.

Their thanks are also due to all their colleagues, too numerous to mention, both at E.M.I. and R.R.E., who have taken part in the work or given the benefit of their advice and encouragement.

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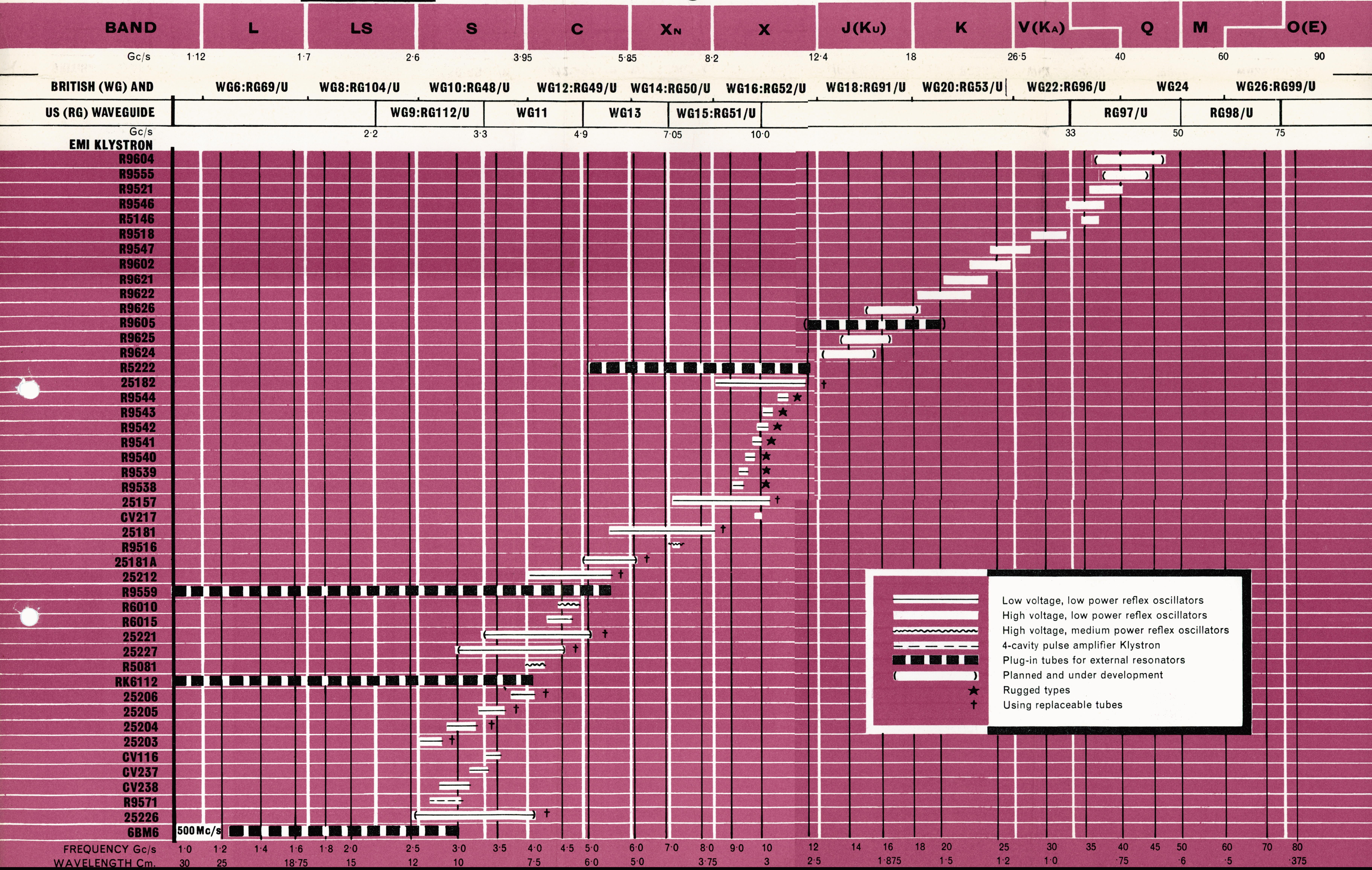
EMI

Klystron and waveguide data

SELECTION CHART



EMI

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R9561
with cavity
25181A

VALVE DIVISION

Typical Characteristics

Cavity Type 25181A with Klystron R9561

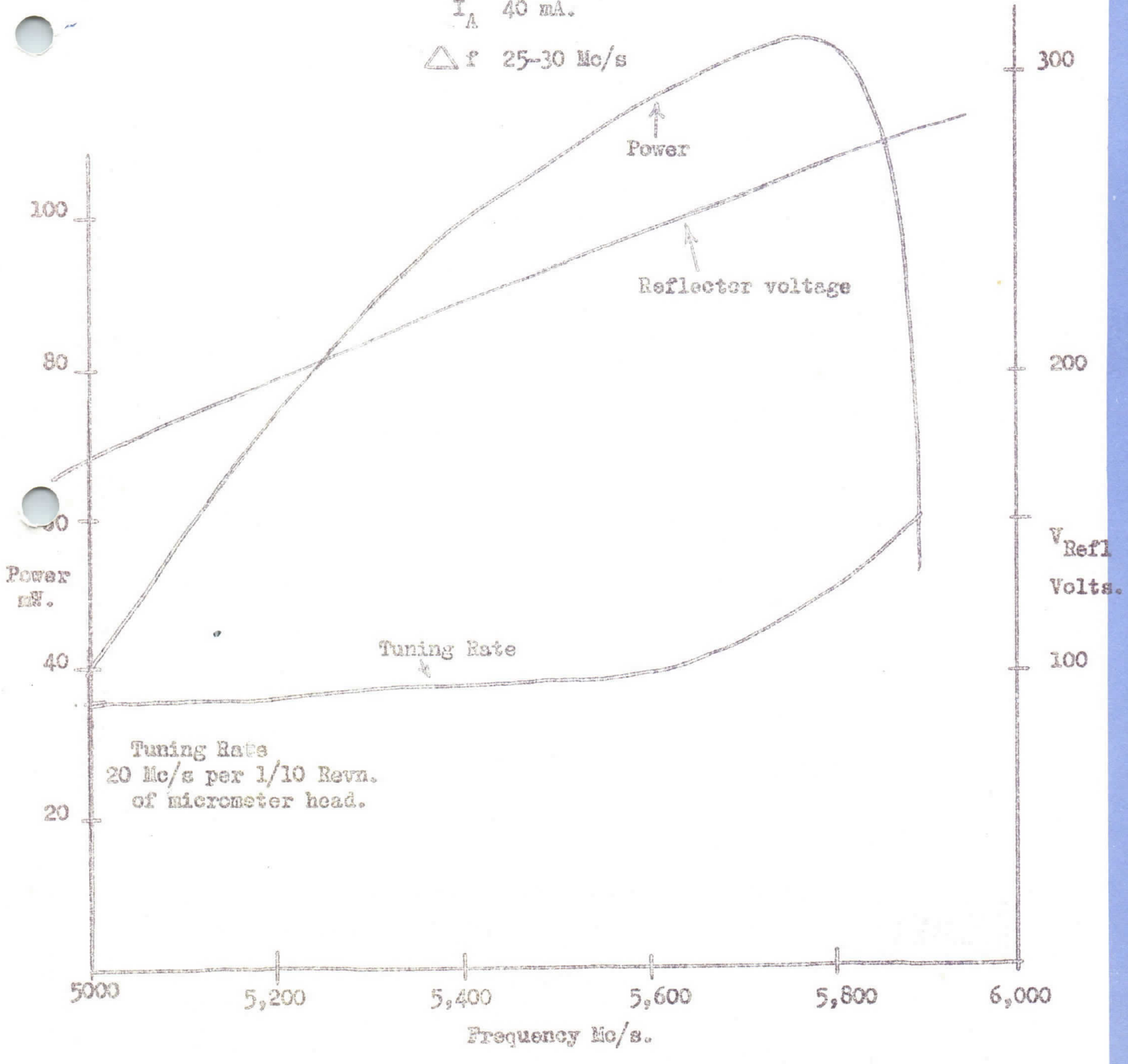
(Modified form of 25181 to give coverage 5000 - 5900 Mc/s.)

V_H 6.3V

V_A 350V

I_A 40 mA.

Δf 25-30 Mc/s



Tuning Rate
20 Mc/s per 1/10 Revn.
of micrometer head.

30.6.60.
JS/GB

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KLXI

4 Cavity Water and Air Cooled X–Band 1KW CW Klystron Amplifier

CATHODE Indirectly heated, impregnated type.

HEATER	V_h (approx)	4.1	V
	I_h	4.8	A

I_h Surge must not exceed 10A. The heater must be run at full current for at least 1 minute before high voltages are applied to the valve.

MAXIMUM RATINGS (All values are absolute)

$V_{collector}$	11.0	kV	
$V_{cavities}$	11.0	kV	
$V_{director}$	-2.0	kV	a
	+0.25	kV	a
$I_{cavities}$	50.0	mA	b
$I_{director}$	15.0	mA	
$P_{collector}$	10.0	kW	c

Load V.S.W.R. (max)
at 0.5 kW output) to be determined
at 1.0 kW output)
at 1.5 kW output)

a (Vcoll and Vcavities should be applied before Vdirector.
(See section on MODULATION.

b With no R.F. drive

c See section on COOLING.

CHARACTERISTICS

Frequency range	9.0-9.6	kMc/s	d
Mechanical tuning range	± 50	Mc/s	e
Small Signal power gain	56-59	dB	f
Saturated power output	1130	W	g

d Valves can be manufactured to operate at any frequency in this range.

e See section on TUNING.

f Synchronous tuned.

g Synchronous tuned.at V_{coll} = 11 kV

TYPICAL OPERATING CONDITIONS

(a) Synchronous Tuned h

$V_{collector}$	8	9	10	11	kV	
$V_{cavities}$	8	9	10	11	kV	
$V_{director}$ (approx)	80	90	100	110	V	j
$I_{collector}$	225	270	295	304	mA	
$I_{cavities}$	25	27	55	96	mA	
$I_{director}$	2	2	2	2	mA	
Magnetic field	700	700	800	800	Oersteds	
Bandwidth	4.5	4.5	4.5	4.5	Mc/s	
P_{out} saturated (approx)	400	630	880	1130	W	
Load V.S.W.R. <	1.05	1.05	1.05	1.05		
Power gain (approx)	50	53	55	57	dB	

(b) Stagger Tuned

$V_{collector}$	8	9	10	11	kV	
$V_{cavities}$	8	9	10	11	kV	
$V_{director}$ (approx)	80	90	100	110	V	j
$I_{collector}$	220	262	288	298	mA	
$I_{cavities}$	30	35	62	102	mA	
$I_{director}$	2	2	2	2	mA	
Magnetic field	700	700	800	800	Oersteds	
Bandwidth (approx)	20	20	20	20	Mc/s	
P_{out} saturated (approx)	490	720	955	1230	W	
Load V.S.W.R. <	1.05	1.05	1.05	1.05		
Power gain (approx)	45	47	50	52	dB	

h In normal practice, the positive side of the high voltage supply is earthed.

j V_{dir} should be adjusted, with no R.F. drive, to give the minimum value of I_{cav} Then with R.F. drive, V_{dir} should be readjusted to give the correct total current (I_{coll} + I_{cav}) for the value of V_{coll} in use.

MAGNETIC FIELD

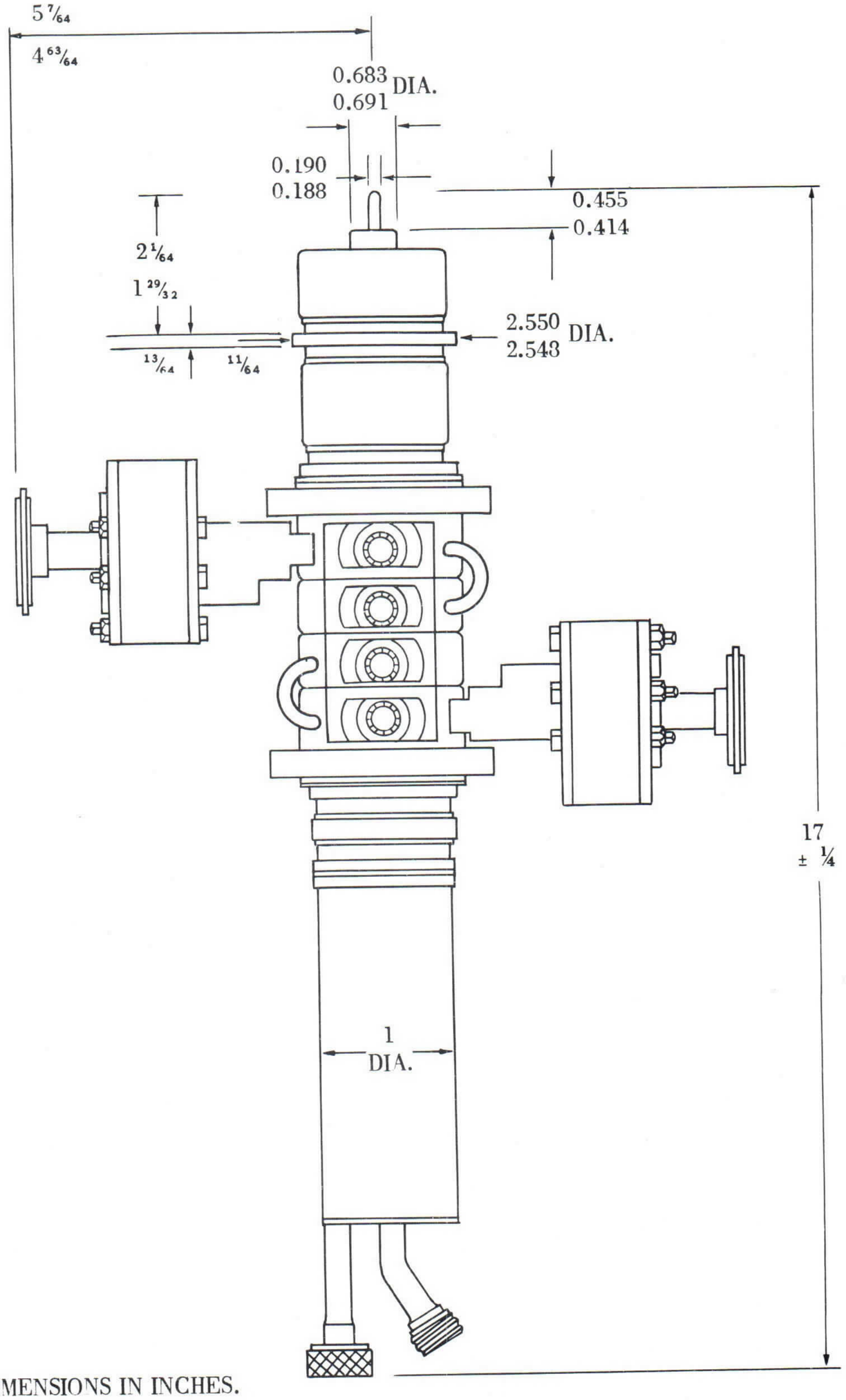
The valve should be operated in a magnetic field whose axis is straight, and whose axis can be adjusted to give the maximum power output.

Drawing No. A57-1534R, available upon request, describes a suitable permanent magnet assembly, capable of the necessary adjustment.

INPUT AND OUTPUT CONNECTIONS

Both R.F. drive and R.F. output connections are by 1 x ½ in. O.D. (W.G.16) waveguide with choke flanges (as shown in the outline drawing).

A short section of flexible waveguide should be used to connect to the R.F. drive and output waveguide flanges.



DIMENSIONS IN INCHES.

TUNING

The cavities are individually tuned over the mechanical tuning range by rotating the tuning knobs through about 6 revolutions.

COOLING

The Collector is fitted with a water cooler. About 100 gallons per hour are required.

The block containing the Cavities is fitted with a water cooler. About 10 gallons per hour are required.

Forced Air cooling of the gun and of the valve is necessary, so that no part of the glass envelope exceeds 150°C in temperature, about 0.4 cubic feet per minute delivered through a 5/16 ins. I.D. tube is sufficient.

Forced air cooling of the output window is required when operating the valve giving more than 1kW CW output. A tube is provided in the output coupling for this purpose. About 0.4 cubic feet per minute is sufficient.

PROTECTION

It is advisable when using an electromagnet for beam focusing to provide a relay to remove the high voltage supplies if the coil supply fails, and similar protection in case of water flow failure, whether permanent or electromagnet focusing is employed.

MODULATION

It is possible to use the Director electrode to modulate the R.F. power output. The negative voltage required, to cut the beam off, ranges from -500 to -1200 volts, depending on $V_{collector}$.

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RESEARCH DIVISION

REFLEX KLYSTRON TYPE R5146

DESCRIPTION

High voltage reflex velocity-modulated oscillator for Q-band operation, having an integral cavity tunable over the range 8-9 mm. (Prototype VX5023). The oxide coated cathode is indirectly heated.

MECHANICAL DATA

See diagram

Output. Waveguide output standard Interservice Coupler, No. Z830,019 to WG22 (.240″ × .140″ I.D.).

Mounting. Any orientation may be used. The output is located with regard to mounting holes on the tuner, as shown in the diagram.

Weight. 14 oz. 400 grammes.

Cooling. To minimize frequency drift, it is recommended that a stream of cooling air should be directed at the envelope. This will also help to maintain a good life.

A: $3\frac{29}{32} \pm \frac{1}{16}$″

B: $\frac{3}{4} \pm \frac{1}{64}$″

C: $4\frac{7}{8} \pm \frac{1}{16}$″

D: $2 \pm \frac{1}{16}$″

E: 0.88 ± 0.005″

F: .475 ± $\frac{1}{64}$″

G: $2\frac{3}{4}$ to $3\frac{1}{4}$″

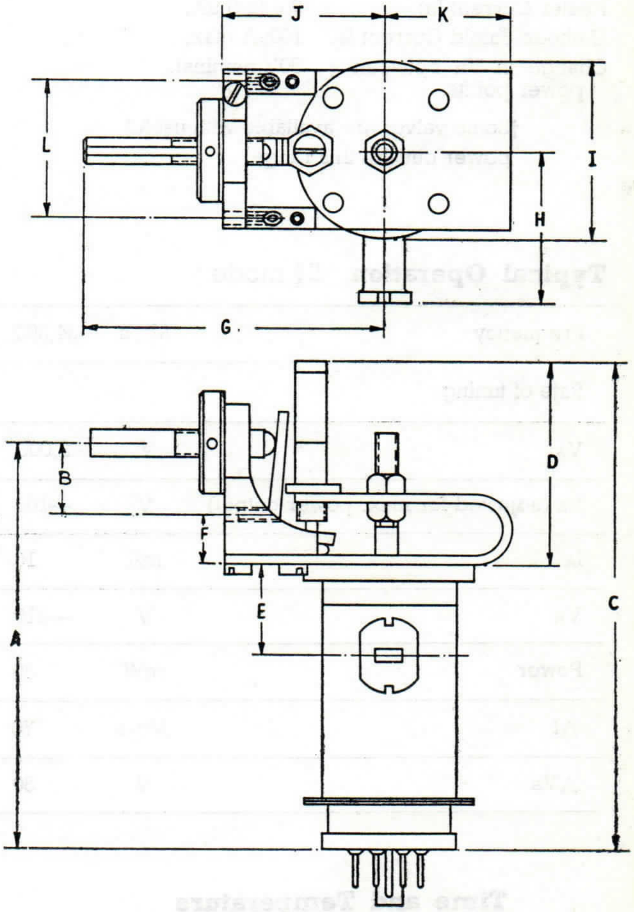
H: $1\frac{9}{16} \pm \frac{1}{64}$″

I: $1\frac{3}{4} \pm \frac{1}{64}$″

J: $1\frac{5}{8} \pm \frac{1}{64}$″

K: $1\frac{5}{16} \pm \frac{1}{64}$″

L: 1.375 ± 0.005″



ELECTRICAL DATA

Base. International Octal.

Connections

PIN 1	PIN 2	PIN 3	PIN 4	PIN 5	PIN 6	PIN 7	PIN 8	ENVELOPE
Cathode Shield	Heater	Internally Connected	Internally Connected	Reflector	Internally Connected	Heater/ Cathode	Internally Connected	Internally Connected to Resonator

... continued overleaf

930

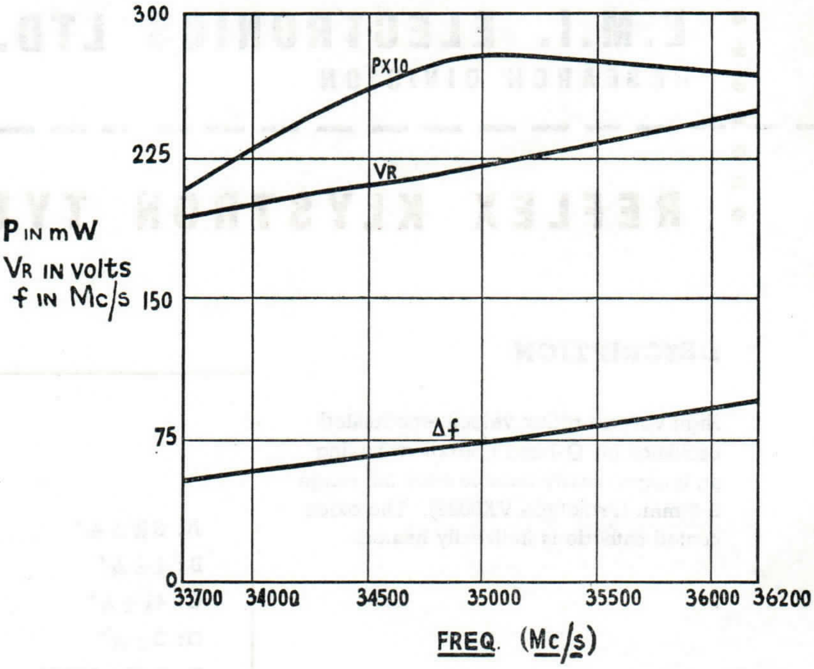
ELECTRICAL DATA

Ratings

(Voltages measured with respect to the cathode)

Resonator Voltage V_A:	2200V max.
Reflector Voltage V_R:	—100 to —500V.
Heater Voltage V_H:	6.3V nominal.
Cathode Shield Voltage V_S:	0 to —200V.
Electronic tuning range Δf between $\frac{1}{2}$ power points.	60 Mc/s nominal on $5\frac{3}{4}$ mode.
Frequency range.	34,000 to 36,000 Mc/s.†
Power output.	15 mW min.
Resonator Current I_A:	12mA max. 8mA min.
Reflector Current I_R:	30μA max.
Heater Current I_H:	0.6 to 0.9A.
Cathode Shield Current I_S:	100μA max.
Change in V_R between $\frac{1}{2}$ power points.	30V nominal.

†Some valves are available with useful power outside this range.



Typical Operation $5\frac{3}{4}$ mode

Frequency	Mc/s	34,000	35,000	36,000	
Rate of tuning			400 Mc/s per rev.		
V_A	V	2,000	2,000	2,000	
V_S (adjusted for max. power output)	V	—100	—100	—100	
I_A	mA	10	10	10	
V_R	V	—210	—240	—270	
Power	mW	30	35	30	
Δf	Mc/s	70	60	50	— (Higher values of Δf are available on modes with lower V_R)
ΔV_R	V	30	30	30	

Time and Temperature Characteristics

With standard tuner and forced air-cooling, operating frequency is achieved in 10 minutes. Without forced air cooling, the period may be up to 30 minutes.

Other forms of tuner giving better time-temperature characteristics are in course of development.

Life

With cooling air and V_H not greater than 6.3V; the life is greater than 1,000 hours.

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Valve Division

REFLEX KLYSTRON TYPE R5222

DESCRIPTION

Low voltage reflex velocity-modulated plug-in X-band oscillator valve, using an external cavity resonator. (Prototype—VX5028 and CV2346.) The oxide coated cathode is indirectly heated.

CONNECTIONS B7G Base (BS488: B7G/1.1)

Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Top Cap	Disc Seals
Internally Connected	Cathode	Internally Connected	Internally Connected	Heater	Cathode Shield	Heater	Reflector	Resonator

RATINGS (Voltage measured with respect to the cathode)

Resonator Voltage V_A:	350V max.	Resonator Current I_A:	50ma max. at 350V. 20ma min. at 300V
Reflector Voltage V_R:	—500V max. Must never be positive	Reflector Current I_R:	4μA max.
Heater Voltage V_H:	6.3V nominal.	Heater Current I_H:	0.6–0.9A
Cathode Shield Voltage V_S:	0V		

Maximum impedance in reflector-cathode circuit 0.25 megohms.

AVERAGE CHARACTERISTICS

Band 8,500–10,000 Mc/s in correctly adjusted $\frac{3}{4}\lambda$ cavities of unloaded Q = 2000

	V_A: 300V I_A: 30mA		V_A: 350V I_A: 40mA	
Mode.	$3\frac{3}{4}$	$4\frac{3}{4}$	$3\frac{3}{4}$	$4\frac{3}{4}$
Power mW.	60	45 (min. 25)	100	70
Min. value of $\frac{\delta f}{\delta V_R}$ Mc/s per V.	0.22	0.45	0.22	0.45
	The valve is free from hysteresis in correctly adjusted cavities.			
Electronic Tuning Range: Δf*— between $\frac{1}{2}$ power points Mc/s	8	15	10	19
Change in V_R: ΔV_R— between $\frac{1}{2}$ power points V	35	25	40	30
V_R for peak power V	—250 to —450	—100 to —260	—250 to —450	—100 to —260

Reflector Tracking. $4\frac{3}{4}$ mode V_A 300V. $V_R = (sf — 335) \pm 6V$ where f in Mc/s., $s=525—550 \times 10^{-4}$V per Mc/s.

*A modified version of the valve is available, which, in suitable cavities, has a value of Δf of about 40 Mc/s in the $4\frac{3}{4}$ mode. (Type R9501).

CATHODE HEATER INSULATION

With 90V applied between cathode and heater (heater — ve to cathode) and a series resistance of 1½ megohms, the current is less than 50μA.

OPERATING TEMPERATURE

The temperature of the valve envelope should not at any point exceed 200°C, nor should that of the external metal parts at any point exceed 150°C. Forced air-cooling may be needed if the valve is mounted in a confined space.

FREQUENCY

Within ± 60 Mc/s of that marked on a standard cavity of approved design.

LIFE

At 300 V, cooled with a flow of air so that cavity temperature does not exceed 35°C, V_H: 6.3V ± 0.05V, the average life is greater than 2,500 hours. At 350V, uncooled, with a cavity temperature ~80°C, the average life is greater than 1,500 hours at V_H: 6.3V ± 0.05V. Both life tests made with the valve switched off 5 minutes in every hour. An improvement in the above figures by a factor of 2 to 3 would be achieved by stabilizing V_H at 5.8V. The heater withstands switching at 7.5V for more than 3,000 cycles of 1¼ minutes on, and 1¼ minutes off.

WARMING-UP TIME

At 6.3V, 1½ minutes is required to reach within 5mW of full power. At 7.5V, ½ minute is required to reach within 5mW of full power. Frequency is within ½ Mc/s of that appropriate to the cavity temperature in the times given above.

OVERALL TEMPERATURE COEFFICIENT

Is slightly less than that due to cavity expansion. Typically, a valve in a brass cavity will show a frequency decrease of 3 Mc/s from 20° to a cavity temperature of 50°C.

STABILITY

Is dependent on voltage supplies. With well stabilized voltages (V_A stabilized to better than 1V, and V_R to better than 0.1V), and at a constant ambient temperature; the frequency varies by less than 200 kc/s over several hours. At steady accelerations of 50g, a frequency deviation of about 1 Mc/s is measured.

NOISE

Excess N.T.R. at 45 Mc/s measured in a broadband crystal mixer with a conversion loss of 6db and 1mW input from the oscillator, is less than 1 in 4¾ mode.

CAVITIES

A tunable cavity for the valve, to cover the range 8500 to 10,000 Mc/s is available. Output coupling is by means of Interservice Coupler to WG16, No. Z830,001. In this cavity, a valve will give about 50mW at 9200 Mc/s, falling off to 25mW at the extremities of the band. The range of frequency obtained for a constant reflector voltage and a power variation of 2 to 1 is ca ± 250 Mc/s at midband and ± 200 Mc/s at the extremities. Two other cavities which extend the range down to 6400 Mc/s are available.

¾ λ radial line cavities of depth 10 mm. may be used for fixed frequencies, the diameter being related to frequency as shown:—

Cavity diameter cm.	4.9	4.5	4.05
Frequency Mc/s	8500	9200	10,000
Optimum loaded Q.	660	660	800

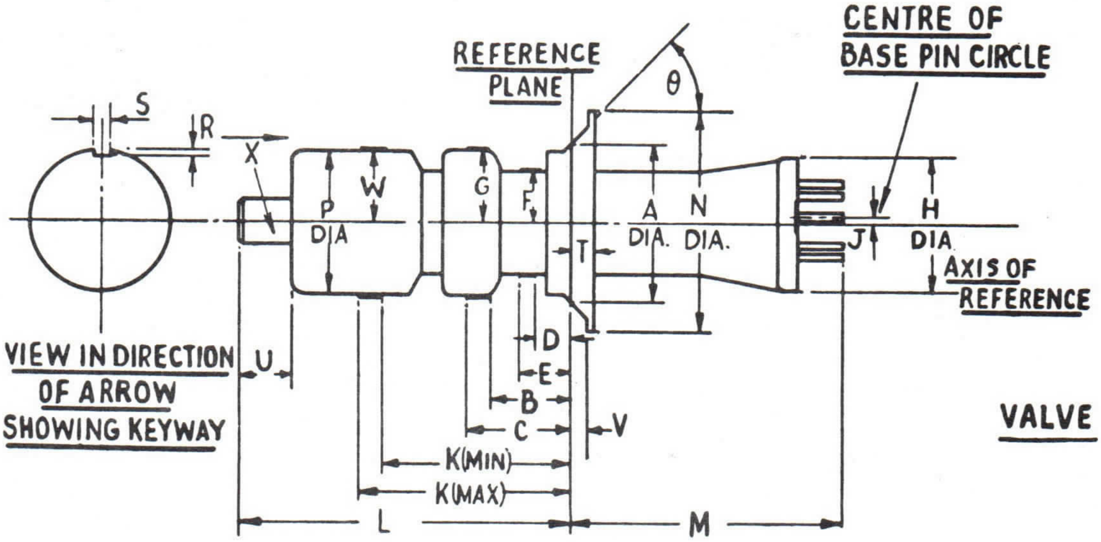
Coupling to the waveguide is conveniently arranged by an output hole of about 8–10 mm. in diameter adjusted for the particular frequency. The conical seating and locking ring for the valve is specified in the diagram.

Narrow range tuning (about 150 Mc/s) may be achieved by insertion of a dielectric rod. A rod of frequentite, 6 mm. in diameter, is suitable.

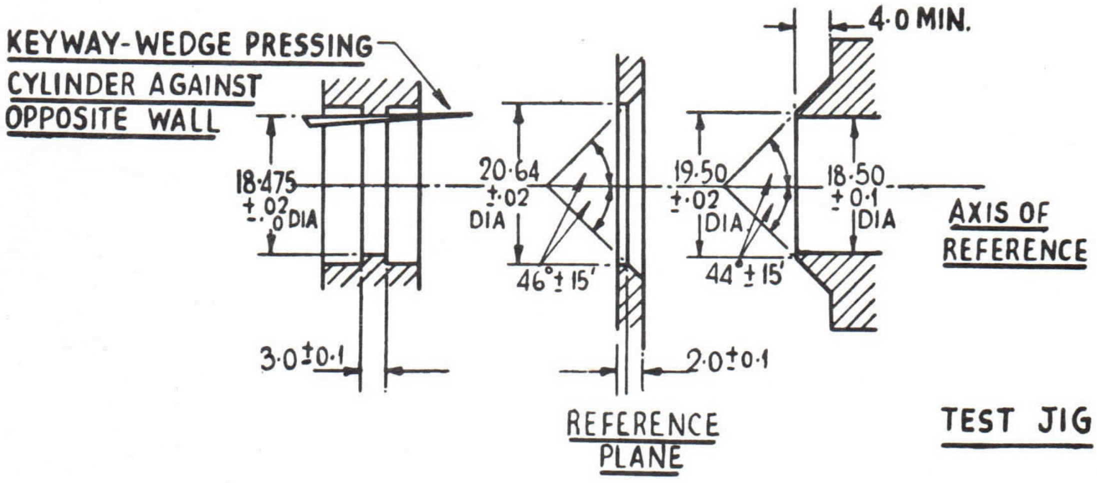
In suitable cavities, the valve may be used at frequencies as low as 5000 Mc/s, and as high as 12,000 Mc/s. Spring finger assemblies for use in cavities are available.

PHYSICAL DIMENSIONS

	Dimensions mm.		Remarks
A	20.64	—	Circle of contact between cone and cavity.
B	10	Max.	—
C	13.6	Min.	—
D	4.5	Max.	—
E	6.5	Min.	—
F	7.0	Max.	Between dimensions D & E.
G	9.34 9.71	Min. Max.	Between dimensions B & C. Incl. eccentricity.
H	18.4	Max.	—
J	1.0	—	Eccentricity of Centre of B7G base pin circle relative to axis of ref.
K	25.0 28.0	Min. Max.	—
L	44.0 47.5	Min. Max.	—
M	36.5 41.5	Min. Max.	—
N	28.7	Max.	—
P	18.30	+.125 —.0	—
R	.825	±0.1	Keyway defines location and prevents rotation in cavity.
S	2.25	±0.1	Slot in line with middle of gap in base pins ±10°.
T	3.0 3.5	Min. Max.	—
U	7.0 8.0	Min. Max.	—
V	2.25	Min.	—
W	9.37	Max.	—
X			Top cap—CT1—conforms to BS. 448: 1953 Section 6/1. 1.
θ	45°		

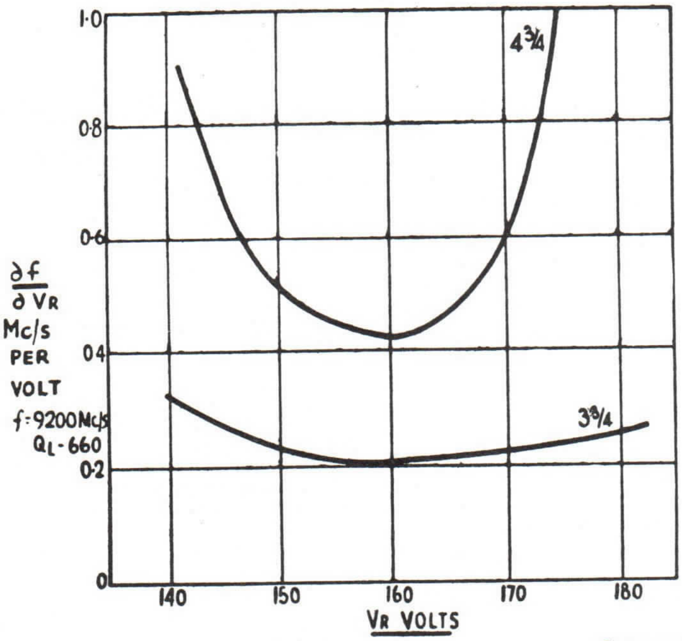


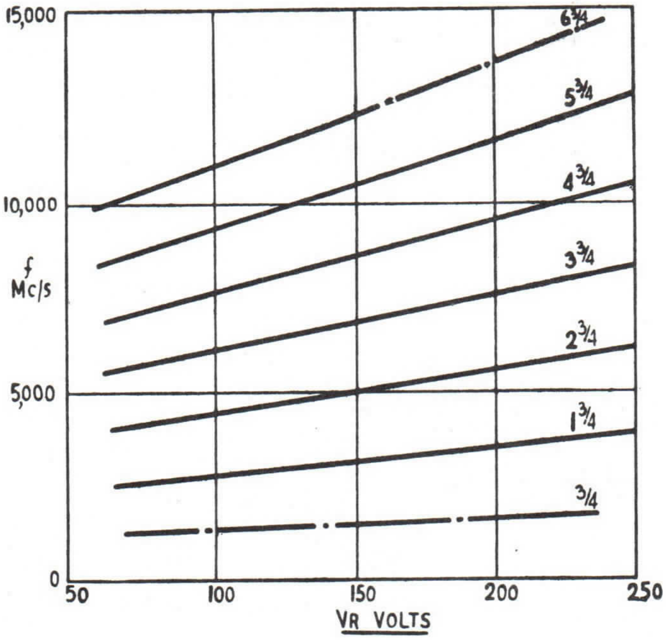
VALVE



TEST JIG

Test jig defines mechanical parameters which are used in checking valves, and which must be taken into account in mechanical design of cavities.





Reflector characteristics of a typical valve
V_A=300V

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E.M.I.

KLYSTRON TYPE RK 6112B

DESCRIPTION

This is a low voltage, reflex velocity modulated valve for use as a local oscillator in the 10 centimetre ("S") Band. It is of the plug-in type, with disc seals for resonator connection, and is indirectly heated.

SPECIFICATION

Power Output	100 mW minimum	Reflector Current	4 micro-amp max.
Frequency Range (with suitable cavity)	2600 - 3700 Mc/s	Cathode Shield Volts *	0
Resonator Voltage *	+ 250 volts	Heater Volts	6.3 volts
Resonator Current	18 - 34 mA	Heater Current	0.7 amp max.
Reflector Voltage * Range	- 60 to - 320 volts		

* Measured with respect to Cathode.

CONNECTIONS

BASE B7G

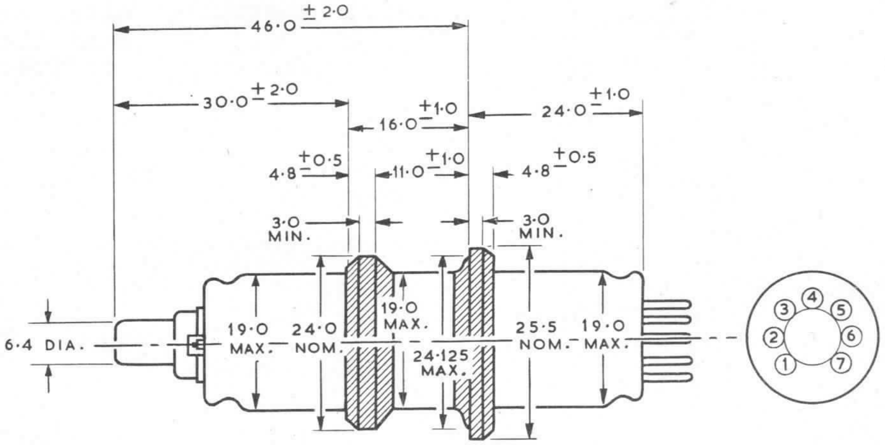
Pin 1	Cathode Shield	Pin 5	Heater
Pin 2	Cathode	Pin 6	Cathode Shield
Pin 3	Blank	Pin 7	Heater
Pin 4	Cathode Shield	Top Cap	Reflector
		Disc Seals	Resonator

PHYSICAL DIMENSIONS

All essential dimensions are included in the fig. overleaf.

CAVITIES

FREQUENCY	TYPE OF CAVITY	APPROXIMATE LOADED Q.
2640 Mc/s	$\frac{1}{4}$ wave radial	140
3200 Mc/s	$\frac{1}{4}$ wave radial	185
3700 Mc/s	$\frac{3}{4}$ wave co-axial	680



DIMENSIONS OF CONTACT COPPERS

CONTACT COPPER	NOMINAL DIAMETER	WILL GO THROUGH RING—GAUGE OF DIA.:	WILL NOT GO THROUGH CALIPERS SEPARATED BY:
LARGE COPPER	25·5	25·63	25·37
SMALL COPPER	24·0	24·13	23·87

MAXIMUM ECCENTRICITIES RELATIVE TO LARGE COPPER

SMALL COPPER	TOP CAP	BASE
0·30	0·45	0·75

ALL DIMENSIONS ARE IN MILLIMETRES

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EMI REFLEX KLYSTRON TYPE R 9516

Description

A reflex velocity-modulated transmitting klystron suitable for F.M. systems, with tunable internal cavity resonator giving 2-3 watts over the range 7050-7300 Mc/s. The R.9516 has a waveguide output system, and should be fixed directly to the end of a length of No. 14 waveguide.

Electrical Parameters, for normal operation

Resonator voltage	(V_A)	1000 V
Resonator current	(I_A)	120 mA
Reflector voltage range	(V_R)	-200 to -550 V
Reflector current	(I_R)	30 μA max.
Screen voltage range	(V_S)	0 to -200 V
Screen current	(I_S)	2 mA max.
Heater	12.6 V	1.0 to 1.25 A
Mechanical tuning range		7050 - 7300 Mc/s
R.F. power output		1.8 W min.
Minimum electronic tuning range for 20% change in electronic tuning slope.		10 Mc/s
Minimum electronic tuning slope.		0.25 Mc/s per V

Operation

A suitable diode should be connected directly between reflector and cathode to avoid damage to the tube on positive excursions of reflector potential, and the h.t. supply must never be applied to the resonator in the absence of negative reflector volts.

The tubes are normally operated with the resonator at earth potential, and the cathode should be pre-heated at normal heater voltage for a minimum period of one and a half minutes before V_A is applied.

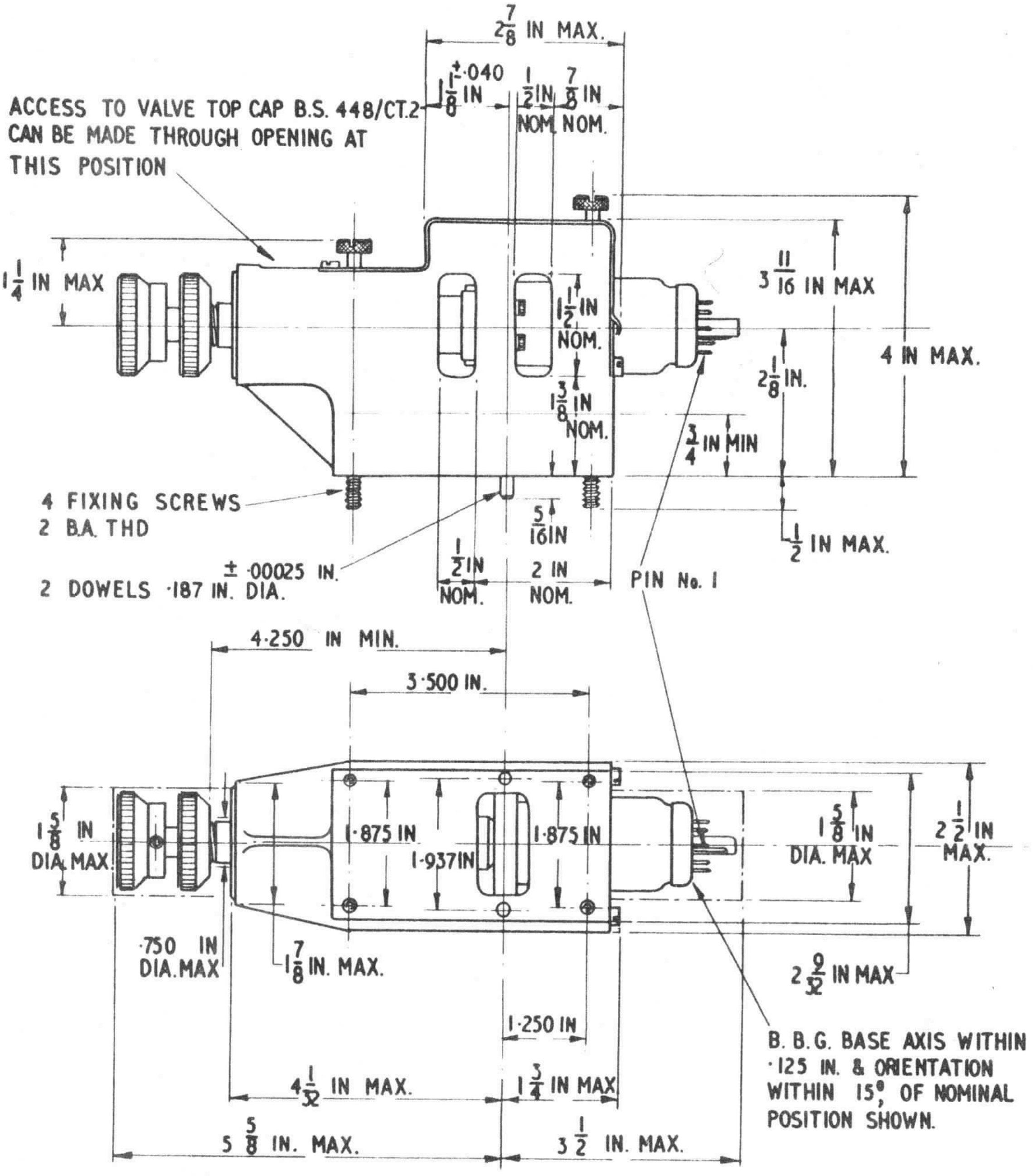
The temperature of the valve envelope must not exceed 200°C and the temperature of the external metal parts must be less than 150°C. Forced air cooling of the resonator is necessary.

Base connections - Base type B8G

Pin No.	1	2	3	4	5	6	7	8	Top cap	Metal body
Electrode	C	IC	CS	H	CS	H	IC	CS	Reflector	Resonator

C = Cathode CS = Cathode shield H = Heater IC = Internal connection

EMI REFLEX KLYSTRON TYPE R9516



M210/2a
DS. 187/2

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Preliminary Details of J-Band Reflex Klystron

Type R9520.

The R9520 is a low voltage integral cavity reflex klystron with an indirectly heated cathode, having a waveguide output to WG18. Tuning is carried out by flexure of a diaphragm which is rigidly coupled to the slightly flexible end of the metal envelope. In the tuning mechanism is a spindle rotated to provide the required movement. The valve is externally similar to type R5146 except for the output coupler.

Nominal Electrical Characteristics (All voltages w.r.t.cathode).

Frequency range 16.2 - 17.2 k Mc/s. The valve is capable of covering the frequency range 15.5-18 k Mc/s., but with low power (min 5 mW) at the extremes of this range.

Anode	V_A 350V	I_A 35 mA.
Heater	V_H 6.3V	I_H 0.6 A.
Cathode Screen	Connect to cathode.	
Power	20 mW (min) over band.	
Reflector	V_R -160V at 16.7 k Mc/s. 4¾ mode.	
E.T.R.	Δf between half power points 45 Mc	

International Octal Base

Pin 1	2	3	4	5	6	7	8
Screen	H	-	-	Refl.	-	C/H	-

Anode connection is made via the metal of the envelope and output flange.

23.7.57.

R9602

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Preliminary data sheet - June, 1960.

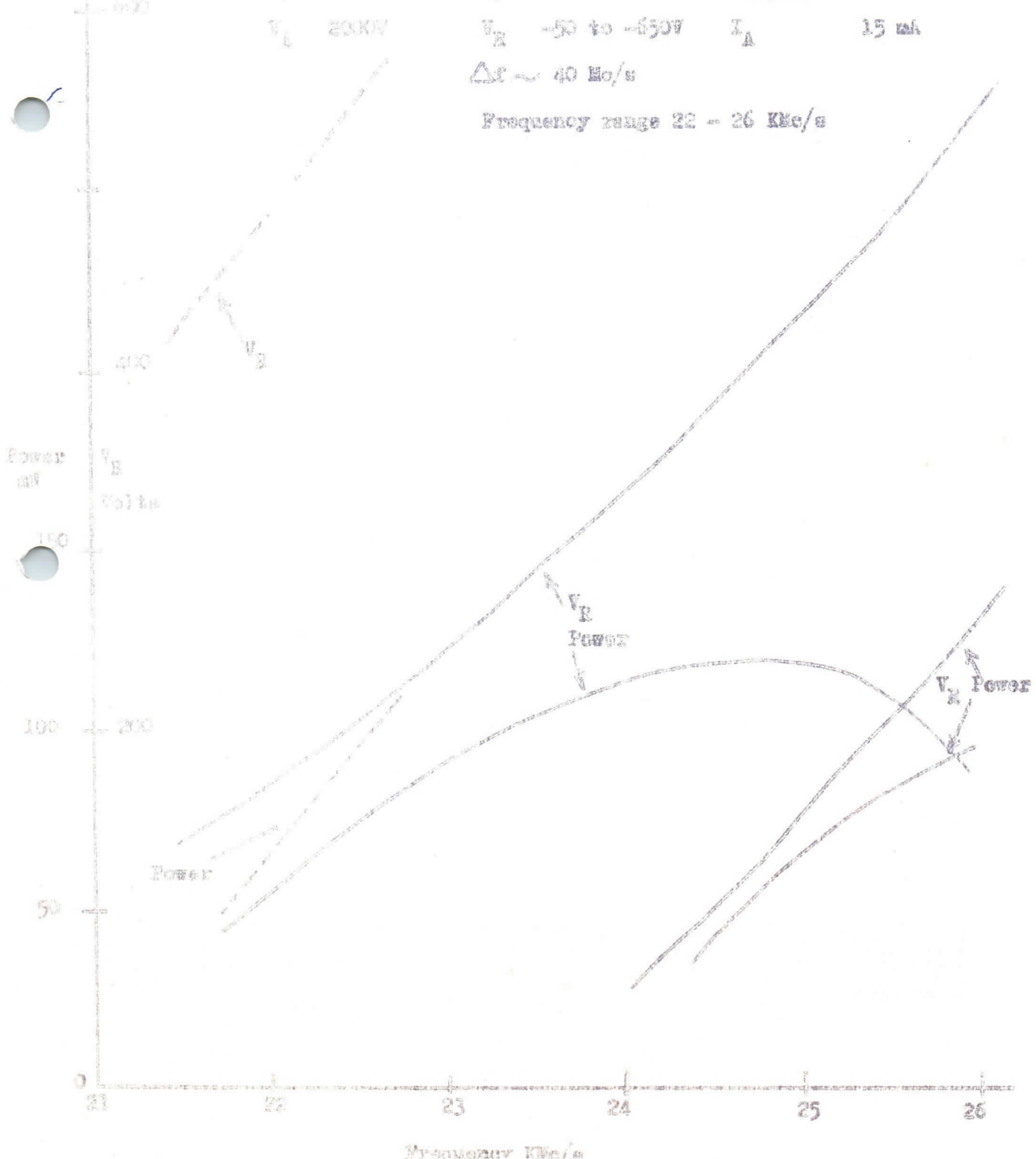
Typical Characteristics of K-Band Reflex Klystron Type R9602.

Integral Cavity Reflex Klystron with UG595/U output flange to WG20. External dimensions and tuner are similar to E.M.I. Q-Band Klystron type R5146, etc.

V_H	6.3V	I_H	0.8A	V_{Screen}	0 to -200V
V_A	2000V	V_R	-50 to -650V	I_A	15 mA

$\Delta f \sim$ 40 Mc/s

Frequency range 22 - 26 KMc/s



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J. Band R9624
R9625
R9626

K Band R9622
R9621
R9602.

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Preliminary Data Sheet

J and K BAND KLYSTRONS

These 2 kV tuneable reflex oscillators are in general design and power supply requirements similar to the well established VX5023 (Q-band) series of tubes.

A summary of their principal characteristics is given below :-

J-Band Output in WG.18 via a flange type 5985-99-083-0030

Type	Frequency Band Gc/s	Typical Power Output
R9624	12.4 - 15.0	100 mW
R9625	13.5 - 16.5	100 mW
R9626	15.0 - 18.0	100 mW

K-Band Output in WG.20 via a flange type UG.595/U

Type	Frequency Band Gc/s	Minimum Power Output	Typical Power Output	Typical E.T.R.
R9622	18.0 - 22.5	40 mW	100 mW	40
R9621	20.0 - 24.0	50 mW	100 mW	40
R9602	22.5 - 26.0	40 mW	85 mW	40

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VALVE DIVISION

EMI KLYSTRON PUMP OSCILLATORS

PROVISIONAL DATA

A series of narrow-band klystrons has been developed from the well-known VX 5023 design. These are suitable as pump sources for masers and parametric amplifiers and typically deliver about ¼ watt.

Type	Centre frequency in the range	Mechanical Tuning	Minimum Power Output	Typical Power Output	Output Section	Output Flange
	Gc/s		mW	mW		
R.9674	26.5-37.5 (Q-band)	5%	175	200	WG 22	083-0018
R.9675	18.0-26.5 (K-band)	5%	175	250	WG 20	UG-595/U
R.9676	12.4-18.0 (J-band)	5%	175	300	WG 18	083-0030

Ratings

Resonator potential	Vres	2500 V.
Resonator current	Ires	15-20 mA
Reflector potential	Vref	-100 to -500
Reflector current	Iref	4μA max.
Screen potential	Vscr	0 to -200 V
Heater potential	V_H	6.3 V
Heater current	I_H	0.8 A

(When ordering, quote centre frequency required).

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EMI PLUG-IN KLYSTRON TYPE R9689
Provisional Data

This improved X-band klystron is completely free from ion oscillation It is ideally suitable therefore for applications using frequency modulation and is recommended as a television link local oscillator and as a low power Doppler speed-measuring transmitter.

Mechanically it is identical to the R5222, CV 2346 and R9537, and may be operated in any external resonator designed for these klystrons.

The tentative electrical specification is as follows:-

			Max	Nominal	Min
Heater voltage	V_H	volts		6.3	
Heater current	I_H	amps	0.9	0.78	0.6
Resonator voltage	V_{RES}	volts	350	300	-
Resonator current	I_{RES}	mA	40	30	20
Reflector voltage	V_{REF}	volts	-500	-	-50
Reflector current	I_{REF}	µA	4	-	-
Power output		mW	-	60	30
Frequency range (in suitable cavities)		k Mc/s	-	5 to 12	-
Electronic tuning range (half-power points)	Δf	Mc/s	-	11	-

A selected klystron, type R9687, is available for the EMI 7000 Mc/s television link as the local oscillator. This is a replacement for the R9537 which will be discontinued.

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Travelling Wave Tube

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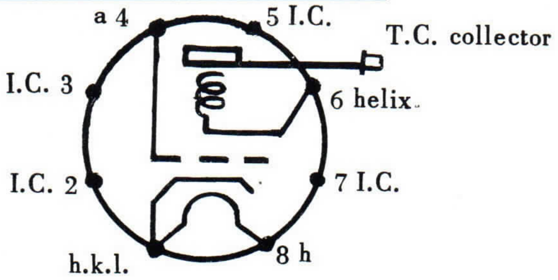
T.W.C.4.

The T.W.C.4. is a convection cooled C-Band Travelling Wave Tube 2 watt C.W. amplifier. It has an indirectly heater cothode.

Valve Dimensions and Base Connection.



View from underside of base.

Base : Octal
Overall length : 14¾" max.
Diameter : 1¼" max.
(See outline drawing for further details)

Heater

Vh	4.0 (approx.)	V
Ih	3.5	A

Ih will be specified on each valve during early production.

Max. Ratings. (All values are absolute)

V coll	3.0	kV (a)
V helix	2.6	kV (a, b)
Va	1.5	kV (b)
I coll	15	mA
I helix	2.0	mA
Ia	2.0	mA
P coll	50	W (c)
Pin (R.F.)	3	W

(a) V coll should always be at least 50 volts greater than V helix.
(b) V helix should be applied befor V_a
(c) See section on COOLING.

Characteristics.

Useable frequency range	6000 - 8000	Mc/s.
Small signal power gain	39	dB (d)
Saturated power output	2	W (d)

Match (input and output) better than 2 : 1, average 1.5 : 1

(d) at V coll = 2.5 kV
I coll = 10 mA
Magnetic field = 600 oersteds.

Typical Operating Conditions (e)

V coll	2.5	2.5	kV
V helix	2.3	2.2	kV (f)
Va	0.8	0.8	kV
I coll	10	10	mA
I helix	1.5	1.5	mA (g)
Ia	0	0	mA
Magnetic field	600	600	Oersteds.
P out	2	1	W
Power gain	35	37	dB
Centre freq.	6500	6500	Mc/s

(e) Pulsed operation is permitted provided the above continuous RATINGS are not exceeded. This enables peak power output in excess of the continuous power output to be obtained.

(f) V helix should be adjusted for optimum output, which should be found within the range ± 100 volts. V helix supply should be stabilised to 1%.

(g) The axis of the magnetic field should be adjusted relative to the tube axis to make I helix a minimum when the apparatus is first installed. Subsequently, when replacing valves, no adjustment should be required.

Magnetic Field.

The valve should be operated in a magnetic field which is uniform within ± 5%, and whose axis should be straight and along the axis indicated on the outline drawing.*

* Suitable magnetic circuits or the design information can be made available.

Cooling.

The collector must be fitted with an external convection cooler, design information being available on request.

The temperature of the hottest part of the tube envelope, including collector, should not exceed 140°C.

Protection.

It is advisable to provide a relay to remove the high voltage supplies if I helix exceeds 2 mA.

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T.W.S.1.

The T.W.S.1 is a convection cooled 2000 Mc/s. Travelling Wave Tube 30 Watt C.W. amplifier with an indirectly heated cathode.

Base Connection (viewed from underside of base)

Pin 1	–	h,k	Pin 5	–	N.C.
2	–	N.C.	6	–	Helix
3	–	N.C.	7	–	N.C.
4	–	a	8	–	h

Base:- Octal

Heater.

V_h	5 max.	V
I_h	5.5 max.	A

I_h will be specified on each valve during early production.

Ratings.

Maximum surge current 10 amps.

V_{coll}	2.5	kV	(a)
V_{helix}	2.4	kV	(a.b)
V_a	2.2	kV	(b)
V_{coll}	90	mA	
I_{helix}	5	mA	
P_{coll}	200	W	(c)
P_{in} (RF)	10	W	

All voltages are measured with respect to cathode.

(a) V_{coll}, should always be at least 50 volts greater than V_{helix}.

(b) V_{helix} should be applied before V_a.

(c) See section on Cooling.

(d) The match on the output should not be worse than 3 : 1

Characteristics

These are average values.

Useable frequency range	1500 - 3000	Mc/s	(e)
Small signal power gain	40	dB	(f)
Saturated power output	30	W	(f)

(e) A design of coupler is available on request, with which the valve has constant gain, within 3 dB, over approximately 25% bandwidth, centred anywhere in this range.

(f) At I_{coll} = 85 mA.

Typical Operating Conditions.

V_{coll}	2.0	kV	
V_{helix}	1.9	kV	small signal operation (g)
V_{helix}	2.1	kV	saturated output operation (g)
V_a	1.4	kV	
I_{coll}	85	mA	
I_a	0.6	mA	
I_{helix}	2.3	mA	(h)
Centre freq.	2000	Mc/s.	(d)

(g) V_{helix} should be adjusted for optimum output, which should be found within the range ± 50 volts. V_{helix} supply should be stabilized to 1%.

(h) The position of the valve should be adjusted in the magnetic field to make I_{helix} a minimum when the apparatus is first installed. Subsequently, when replacing valves, no adjustment should be required.

Magnetic Field.

The valve should be operated in a magnetic field whose axis should be straight and along the axis indicated on the outline drawing.

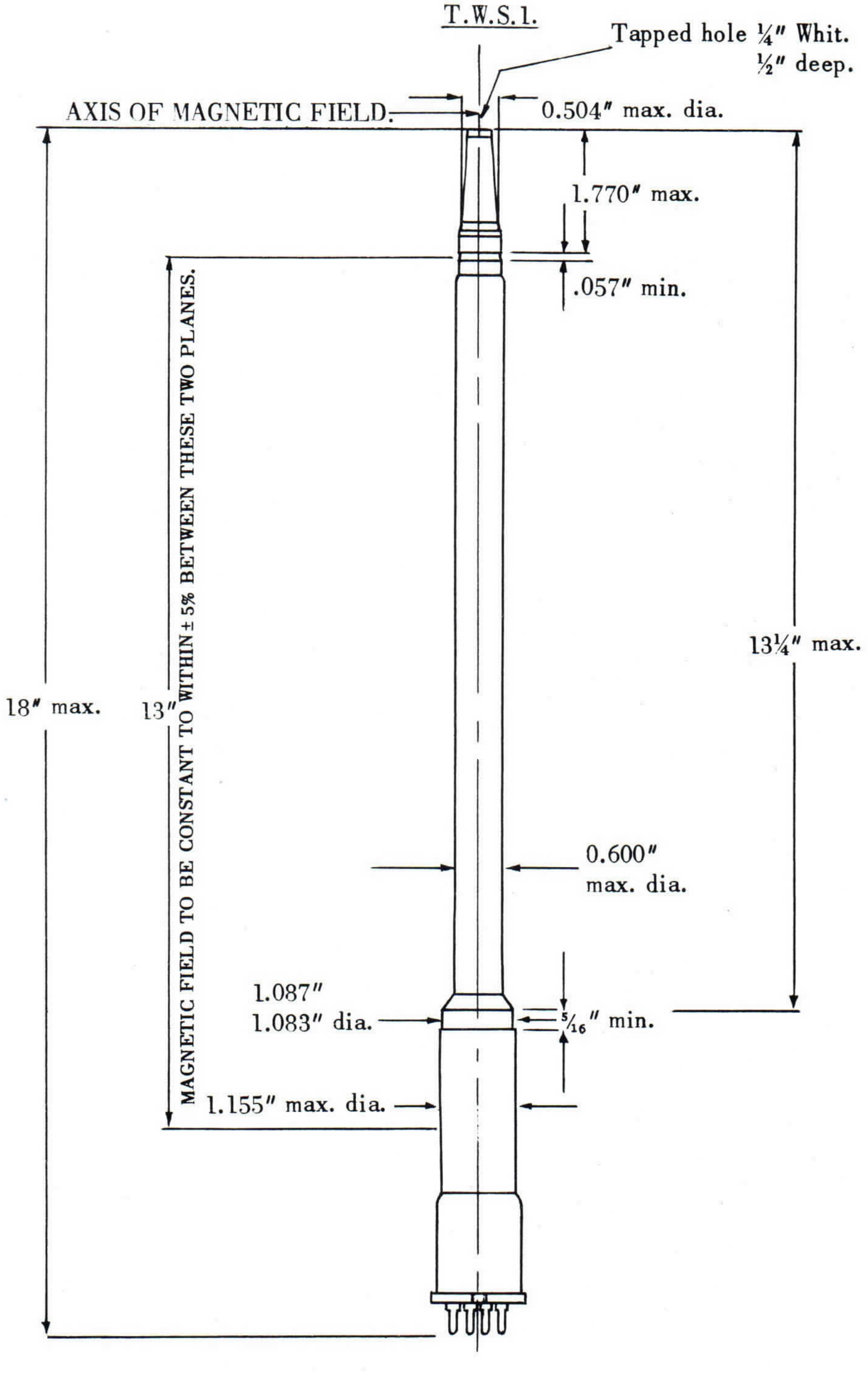
Drawings, available on request, describe a suitable convection cooled solenoid, dissipating about 140 watts.

Cooling.

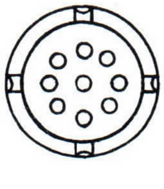
The collector must be fitted with an external cooler. Drawings, available on request, describe a suitable convection air cooler.

Protection.

It is advisable to provide a relay to remove the high voltage supplies if I_{helix} exceeds 5mA.



T.W.S.1.
Tapped hole ¼″ Whit. ½″ deep.
AXIS OF MAGNETIC FIELD.
0.504″ max. dia.
1.770″ max.
.057″ min.
MAGNETIC FIELD TO BE CONSTANT TO WITHIN ± 5% BETWEEN THESE TWO PLANES.
13″
18″ max.
13¼″ max.
0.600″ max. dia.
1.087″ 1.083″ dia.
5/16″ min.
1.155″ max. dia.



TD

The Company reserves the right to modify these designs and specifications without notice.

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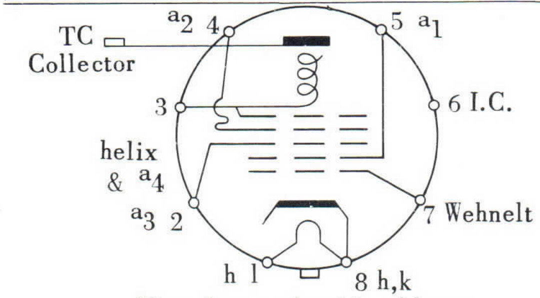
VALVE DIVISION

TWS2

The TWS2 is a Low Noise Travelling-wave Tube Amplifier for use between 1700-2700 Mc/sec. It has an indirectly heated oxide coated cathode.

VALVE DIMENSIONS AND BASE CONNECTIONS

Base: Octal
Overall length: 400 max. mm.
Diameter: 32 max. mm.
(See OUTLINE drawing for further details)



View from underside of base.

HEATER

V_h	6.3 (average)	V	(a)
I_h	0.5 (approx.)	A	

(a) V_h should be adjusted to give the best noise figure; this value will be specified on each valve.

RATINGS

V_{coll}	600 max.	V	
V_{helix}	350 max.	V	
V_{a1}, V_{a2}, V_{a3}, V_{a4}	350 max.	V	
I_{coll}	1.0 max.	mA	
I_{helix}	20 max.	μA	
I_k	1.0 max.	mA	
$I_{a1}+I_{a2}+I_{a3}+I_{a4}$	20 max.	μA	
P_{coll}	0.6 max.	W	(b)
P_{in} (RF)	2 max.	W	

(b) See section on INSTALLATION.

CHARACTERISTICS

Useable Frequency Range	1600-2600	Mc/s	(c)
Small Signal Power Gain	25	dB	(d)
Saturated Power Output	3	mW	(d)
Noise Figure	7-9	dB	(d,e)

(c) A design of coupler is available upon request, with which the valve has constant gain, within 3dB over approximately 25% bandwidth, centred anywhere in this range.

(d) At (V_{coll} = 550 V
(I_{coll} = 0.5mA
(Magnetic field = 400 Oersteds

(e) Over the frequency range of the coupler described in footnote (c).

TYPICAL OPERATING CONDITIONS

Low Noise Amplifier

V_{coll}	550	550	V	(g
V_{helix}, V_{a4} (strapped)	300	307	V	(g,h)
V_{a3}	200	200	V	(g,h)
V_{a2}	80	80	V	(g,h)
V_{a1}	25	50	V	(g,h)
$V_{wehnelt}$	40	40	V	(g,h)
Magnetic field	400	400	Oersteds	(g)
I_{coll}	500	950	μA	
I_{helix}	1.0	1.0	μA	(j)
$+I_{a2}$	1.0	1.0	μA	(j)
Power gain	25	32	dB	
Noise Figure	7-9	16	dB	(f)
Centre Frequency	2200	2200	Mc/s	
Bandwidth (to 3dB points)	550	550	Mc/s	(c)

(g) See setting-up instruction in INSTALLATION section.

(h) Supplies for these electrodes should be adjustable within the following ranges, and after adjustment should be stabilized to within ± 1%.

V_{helix}	(range)	250-350	V
Va3	(range)	150-350	V
V_{a2}	(range)	50-150	V
V_{a1}	(range)	0-50	V
$V_{wehnelt}$	(range)	0-80	V

INSTALLATION

The specified V_h should be applied.

In the initial alignment of the tube, V_{a1}, which controls the beam current, should be reduced so that none of the above RATINGS are exceeded.

The position of the valve should now be adjusted in the magnetic field to make I_{helix} a minimum of less than 1μA, and V_{helix} adjusted for optimum gain.

V_{a2} should then be adjusted to give minimum noise output from the tube. The subsidiary noise adjustments are made by varying V_{a3} and $V_{wehnelt}$, at the same time maintaining I_{coll} at the required current by adjusting V_{a1}.

The tube should be operated in a magnetic field whose axis should be straight and along the axis indicated on the OUTLINE drawing. *

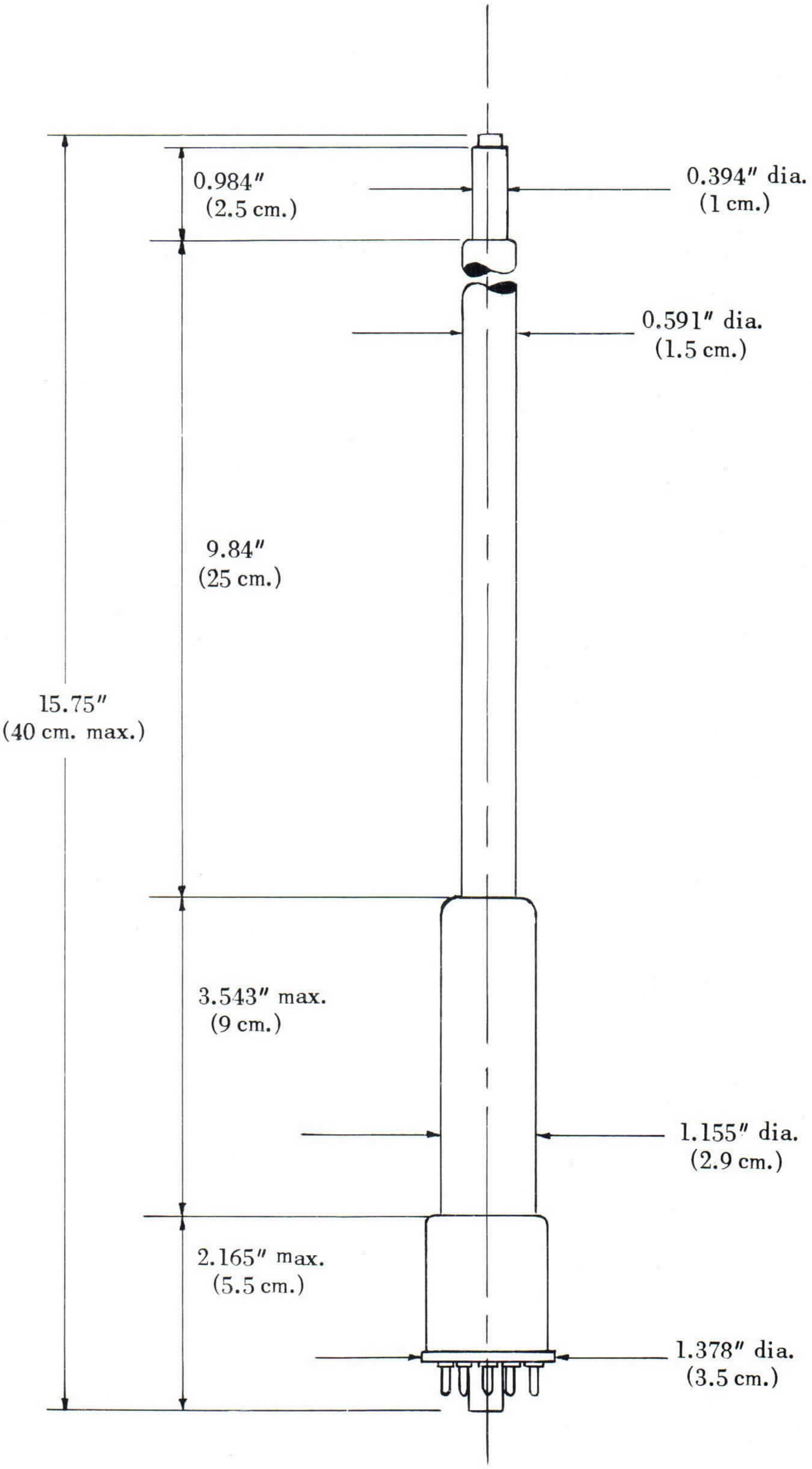
The value of the field strength should be uniform within ± 5% between the planes indicated on the OUTLINE drawing.

The tube may be operated in any position.

The temperature of the hottest part of the tube envelope, including collector, should not exceed 140°C.

* A suitable magnetic circuit or the design information can be made available.

TWS2.
E2801.


0.984″
(2.5 cm.)
0.394″ dia.
(1 cm.)
0.591″ dia.
(1.5 cm.)
9.84″
(25 cm.)
15.75″
(40 cm. max.)
3.543″ max.
(9 cm.)
1.155″ dia.
(2.9 cm.)
2.165″ max.
(5.5 cm.)
1.378″ dia.
(3.5 cm.)

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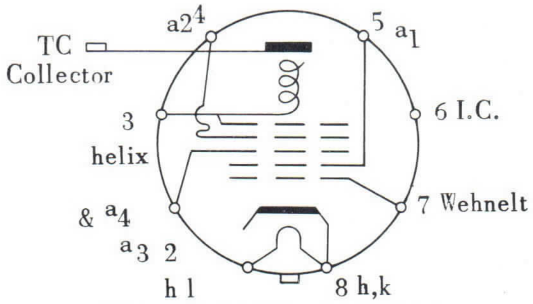
VALVE DIVISION

TWS3

The TWS3 is a Low Noise Travelling-wave Tube Amplifier for use between 2700-4100 mc/sec. It has an indirectly heated oxide coated cathode.

VALVE DIMENSIONS AND BASE CONNECTIONS



View from underside of base.

Base: Octal
Overall length: 345 max. mm.
Diameter: 32 max. mm.
(See OUTLINE Drawings for further details)

HEATER

V_h	6.3 (average)	V	(a)
I_h	0.5 (approx.)	A	

(a) V_h should be adjusted to give the best noise figures; this value will be specified on each valve.

RATINGS

V_{coll}	600 max.	V	
V_{helix}	350 max.	V	
V_{a1}, V_{a2}, V_{a3}, V_{a4}	350 max.	V	
I_{coll}	1.0 max.	mA	
I_{helix}	20 max.	μA	
I_k	1.0 max.	mA	
$I_{a1} + I_{a2} + I_{a3} + I_{a4}$	20 max.	μA	
P_{coll}	0.6 max.	W	(b)
P_{in} (RF)	2 max.	W	

CHARACTERISTICS

Useable Frequency Range	2700-3700	Mc/s	(c)
Small Signal Power Gain	25	dB	(e)
Saturated Power Output	3	mW	(e)
Noise Figure	7-10	dB	(d,e)

(c) A design of coupler is available upon request.

(d) At V_{coll} = 500V
I_{coll} = 0.5mA
Magnetic field = 500 Oersteds.

(e) Over the frequency range of the coupler.

TD

TYPICAL OPERATION CONDITIONS

Low Noise Amplifier

V_{coll}	500		V	
V_{helix}, V_{a4} (strapped)	250	approx.	V	(g,h)
V_{a3}	200	approx.	V	(g,h)
V_{a2}	80	approx.	V	(g,h)
V_{a1}	25	approx.	V	(g,h)
$V_{wehnelt}$	40	approx.	V	(g,h)
Magnetic field	500		Oersteds	
I_{coll}	500		μA	
I_{helix}	0.5		μA	(j)
$I_{a1} + I_{a2} + I_{a3} + I_{wehnelt}$	1.0		μA	(j)
Power gain	25		dB	
Noise Figure	7-10		dB	(f)
Centre Frequency	3200		Mc/s	

(g) See setting-up instructions in INSTALLATION section.

(h) Supplies for these electrodes should be adjustable within the following ranges, and after adjustment should be stabilized to within ± 1%.

V_{helix} range	250 - 350	V
V_{a3} range	150 - 350	V
V_{a2} range	50 - 150	V
V_{a1} range	0 - 50	V
$V_{wehnelt}$ range	0 - 80	V

INSTALLATION

The specified V_h should be applied.

In the initial alignment of the tube, V_{a1}, which controls the beam current, should be reduced so that none of the above RATINGS are exceeded.

The position of the valve should now be adjusted in the magnetic field to make I_{helix} a minimum of less than 2μA and V_{helix} is adjusted for optimum gain.

V_{a2} should then be adjusted to give minimum noise output from the tube. The subsidiary noise adjustments are made by varying V_{a3} and $V_{wehnelt}$, at the same time maintaining I_{coll} at the required current by adjusting V_{a1}.

The tube should be operated in a magnetic field whose axis should be straight and along the axis indicated on the OUTLINE drawing. *

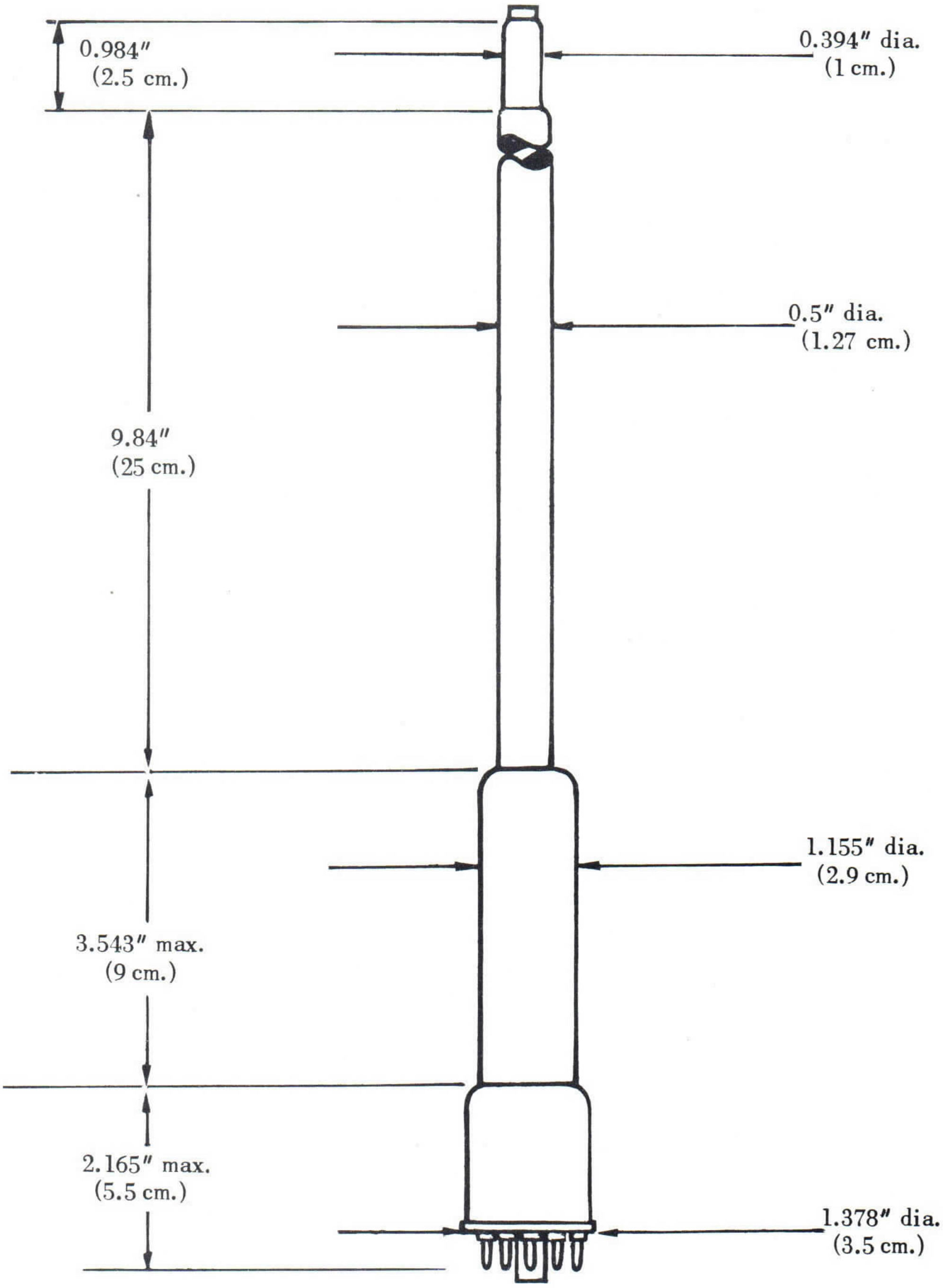
The value of the field strength should be uniform within ± 5% between the planes indicated on the OUTLINE drawing.

The tube may be operated in any position.

The temperature of the hottest part of the tube envelope, including collector should not exceed 140°C.

* Suitable magnetic circuits or the design information can be made available.

TWS3.
E2802.


0.984″
(2.5 cm.)
0.394″ dia.
(1 cm.)
0.5″ dia.
(1.27 cm.)
9.84″
(25 cm.)
1.155″ dia.
(2.9 cm.)
3.543″ max.
(9 cm.)
2.165″ max.
(5.5 cm.)
1.378″ dia.
(3.5 cm.)

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BACKWARD WAVE OSCILLATOR - TYPE 30036.

Frequency : 'S' band, electronically tunable

Power output: 20mW, minimum

Construction: Packaged, permanent magnet

Modulation : Amplitude, pulse or frequency.

CHARACTERISTICS

		Min.	Max.	
Frequency electronically tunable over the range		2.4	4.5	Gc/s
Delay structure voltage	f=2.4Gc/s	150.	200	V
	f=4.5Gc/s	1.03	1.17	kV
Sensitivity over frequency range		1.2	7.0	Mc/s per V
Power output over frequency range		20.	-	mW
Grid voltage for maximum output		-	0	V
for zero output		-	-100	V

CATHODE

Indirectly heated :	Vh	6.3	V
	Ih	2.7	A
	Ih (surge max.)	4.0	A

The cathode must be heated for at least 2 minutes before application of h.t. voltage.

TYPICAL OPERATION

f	2.4	3.4	4.5	Gc/s
Vdelay structure	0.175	0.44	1.15	kV
Idelay structure	20.	23.	26.	mA
Va	170	170	170	V
Ia	1.0	1.0	1.0	mA
Vg	0	0	0	V
Pout	25	200	300	mW

OPERATING NOTE

Electrode supplies must be connected in the following order and disconnected in the reverse order :

1	2	3	4
heater	grid	delay structure	anode

COOLING

Forced air

Tmount max. (at specified point)	120	°C

LIMITING VALUES (absolute ratings)

Vdelay structure max.	1.5	kV
Vdelay structure min.	150	V
pdelay structure	60	W
Ik max.	50	mA
Va max.	200	V
Ia max.	5.0	mA
+Vg max.	0	V
-Vg max.	150	V
vh-k(pk) max.	±50	V

MOUNTING POSITION : Any

OUTPUT CONNECTION : 50 ohm coaxial line N-type

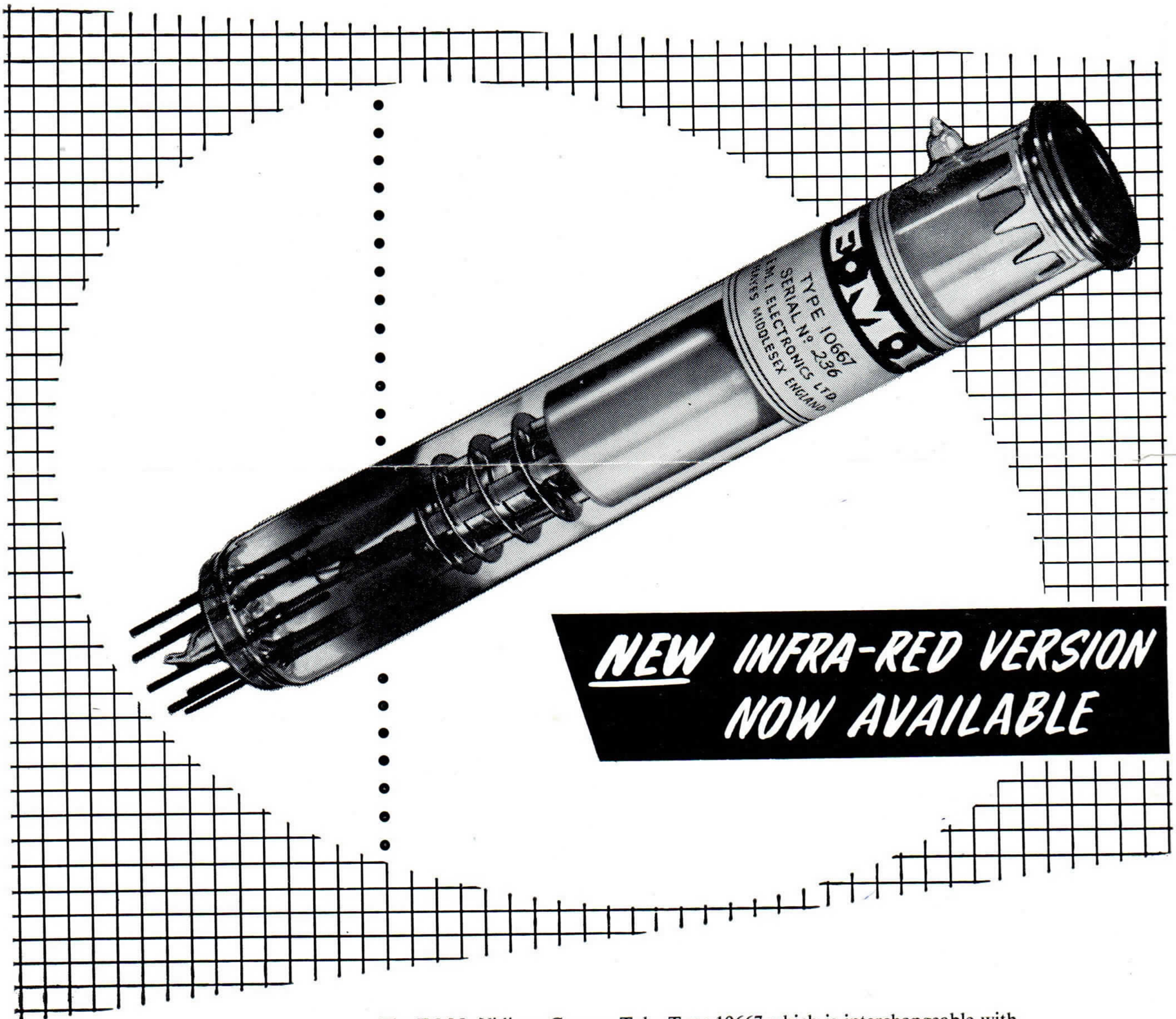
EC8/19
9.5.1960.

Camera Tubes

~~10667~~
10667

E·M·I

Vidicon Camera Tube



The E.M.I. Vidicon Camera Tube Type 10667 which is interchangeable with the American types is now available in three versions.

Type 10667S—Studio Camera use. **Type 10667F**—Film Pick-Up
Type 10667G—Industrial Applications
For comprehensive details please apply for technical brochure

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Studio and Interview Camera Channels. Flying Spot and Photoconductive Film Channels. Studio Mixers and Control Equipment

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Telephone: SOUthall 2468 Ext. 316

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VALVE DIVISION

EMI CAMERA TUBES AND STORAGE TUBES

These are all of nominal diameter 1 in (25.4 mm), 1.135 in (25.7 mm) max. excluding side pip, and have 6.3 V. 0.6 A heaters. Test and normal operation are at V_A 300 V (max. V_A is 500 V) and room temperature, although the tubes will operate over the range 0 to 60° C. Image size is 0.500 inch (12.7 mm) x 0.375 inch (9.5 mm). Minimum modulation at 400 T.V. Lines - 12 dB (300 V operation).

Type	Typical Output Current		Typical Cathode Illumination		Notes
	Black µA	White µA	White lm/ft^2	Max. lm/ft^2	
10667SC	0.005	0.25	5	1000	For colour studio use in simultaneous colour cameras.
10667S	0.005	0.25	5	1000	For studio use
10667F	0.002	0.3	50	1000	For motion-picture film pick up
10667G	0.01	0.16	2	1000	For Industrial T.V.
10667T	0.01	0.25	2	1000	For Industrial T.V. (high sensitivity) 10667TX - specially selected for use with X-ray Image Intensifiers.
10667M	0.01	0.16	2	1000	Setting up purposes and amateur use
10667IR	0.05 to 0.10	0.15	16+Wratten 87 filter	-	IR sensitive up to 10,000 Å For signal = 0.15 µA and dark current - 0.05 µA. Sensitivity = 0.018 µA/µW/cm^2 at 5200 Å - 0.0011 µA/µW/cm^2 at 8500 Å gamma = 0.7
10667UV	0.01	0.2	2500 Å to 6000 Å	-	Quartz faceplate For dark current of 0.01 µA Sensitivity = 0.2 µA/µW/cm^2 at 4000 Å = 0.1 µA/µW/cm^2 at 2537 Å gamma = 1

10667L See storage tubes overleaf.

Note: 1 lm/ft^2 (lumen per square foot) = 1 foot-candle = 10.764 lx (lux).

EMI CAMERA TUBES AND STORAGE TUBES (Cont'd)

C.P.S. EMITRON TUBE:

With tri-alkali photosensitive mosaic, this cathode potential stabilised Tube is capable of giving excellent pictures of high signal to noise ratio with a lens aperture of *f*11, and a scene brightness of 100 ft.lamberts.

Type	Typical Output Current		Cathode Illumination		Image Size	Minimum Modulation at 400 TV Lines	Temp. Range
	Black μA	White μA	White lm/ft^2	Max. lm/ft^2	Millimetres (inches)		°C
10764A	0	0.15	0.12	50	45.2 x 34 (1.78 x 1.34)	-6 dB	20-50

IMAGE ORTHICON TUBE - 4½ INCH:

Type	Typical Signal Output	Cathode Illumination		Image Size	Minimum Modulation at 400 TV Lines	Temp. Range
	μA	White lm/ft^2	Max. lm/ft^2	Millimetres (inches)		°C
9564	12	0.04	50	32.5 x 25.2 (1.32 x 0.99)	-7 dB	35-50
9565	16	0.08	50	32.5 x 25.2 (1.32 x 0.99)	-7 dB	35-50

STORAGE TUBES:

Type		Focus and Deflection	Storage Capacity (unit signals)	Storage Time
Single Read-out				
9511A Barrier Grid Storage		Electrostatic	20,000	Several hours
10764	Photosens, mosaic	Electromagnetic	30,000	1 min 25°C
	plus barrier grid			1 hour -40°C
Continuous Read-out				
Vidicon 10667L		Electromagnetic	Half tones	Fading in 1-3 minutes

The supply of vidicons by EMI Electronics Ltd. does not thereby include or imply any licence under EMI's British Patent No. 665877.

EMI Electronics Ltd Valve Division

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Source ④

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CAMERA TUBES AND STORAGE TUBES

Vidicons: These are all of nominal diameter 1", (1.135" max, excluding side pip) and have 6.3V, 0.6A heaters. Tests and normal operation are at V_A 300V, (Max V_A is 350V) and room temperature, although the tubes will operate over the range 0 to +60° C. Resolution capability is 500 lines for ½" x ⅜" image.

Type	Output Current Black µA	Output Current White µA	Cathode Illumination White ft.C	Cathode Illumination Max. ft.C	Notes
10667UV	0.01	0.2	2	1000	Quartz faceplate. At 2500 A.U. gives good picture when photographic plate needs ¼ sec exposure
10667IR	0.05	0.2	50 + Wratten 87 filter	250	Infra red sensitive up to 10,000 A.U.
10667G	0.01	0.2	2	1000	For industrial T.V.
10667F	0.004	0.3	100	1000	For motion-picture film pick up.
10667S	0.005	0.25	5	1000	For studio use.

C.P.S. Orthicon Tubes: Having tri-alkali photosensitive mosaics, these cathode potential stabilised pick-up tubes are capable of giving excellent pictures of high signal to noise ratio with a lens aperture of f11, and a scene brightness of 100 ft. lamberts.

Type	Output Current Black µA	Output Current White µA	Cathode Illumination White ft.C	Cathode Illumination Max. ft.C	Image Size Inches	Resolution Capability Lines	Temp. Range °C
10764A	0	0.15	0.12	50	1.78x1.34	500	0-50
10764B	0	0.10	0.18	50	1.29x0.98	400	0-50

Image Orthicon: Suitable for operation at f.5.6 and 5-20ft. lamberts.

9549	30	15	0.015	50	1.29x0.98	500	35-50

Storage Tubes:

Type		Focus Deflection	Storage Capacity (unit signals)	Storage Time
9511A	Barrier Grid storage	Electrostatic	20,000	10 min.
10764	Photosens. Mosaic plus barrier grid	Electromagnetic	30,000	1 min 23°C 1 hr.-40°C

(The Company reserve the right to make changes without prior notice.)

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9549

E.M.I. ELECTRONICS LTD.

?

IMAGE ORTHICON PICK-UP TUBE TYPE R9549

The 9549 is a television camera tube intended for both outdoor and studio pick-up. Of the image orthicon type, having a photocathode from which electrons are accelerated and focussed onto a thin glass target, the tube has a low-velocity electron scanning beam which is modulated by the charges on the target corresponding to areas of light and dark, and returned to an electron multiplier at the gun end of the tube. For correct operation, the target must be kept at the optimum temperature given below, while temperature gradients along the tube which might cause caesium migration, must be avoided.

The photocathode is of the Bi-Ag-Cs-O, (S10), type, which has good response in the blue, green and red region of the spectrum.

Under proper operating conditions, the 9549 has light transfer characteristics such that gamma correction is not required.

The 9549 will operate in place of RCA type 5820, or EEV type

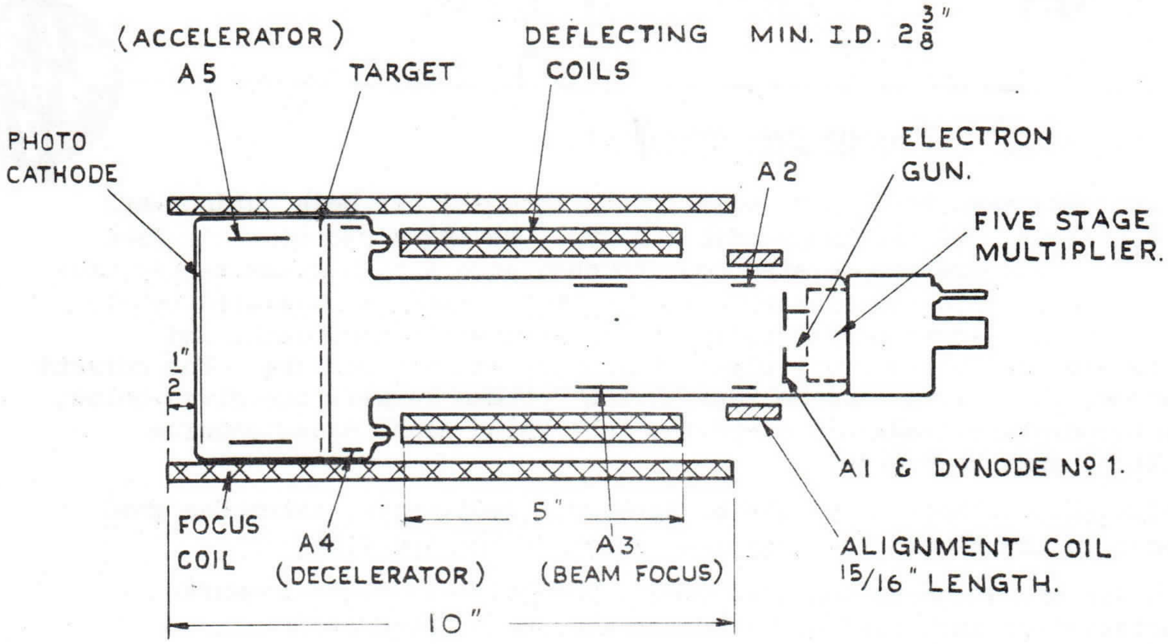
CHARACTERISTICS

Mechanical (See fig. overleaf.)

Bulb diameter.	3 ± 1/16"	Neck diameter 2 ± 1/16"	
Overall length	15.3/16" ± 1/4"	Useful size of cathode 1.6" max. diag.	

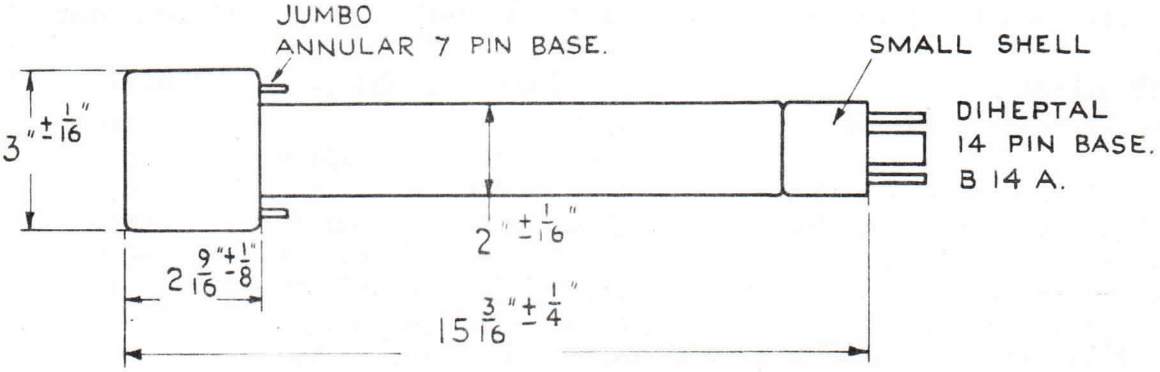
Electrical		Max.	Typical	Min.
Photocathode sensitivity	µA/L		35	20
" voltage	Volts	-550	-400 *	-300
" illumination	ft.c.	50		
A5. (Accel. 75% of cathode)	Volts.	-550	-300 *	-200
Target voltage	Volts	10	0 to 3 *	-10
A4. (Decelerator)	Volts	150	0 to 125 *	0
A3. (Beam focus)	Volts	300	160 to 220 *	-
A2. (Adjusted for max uniformity)	Volts	400	225 to 330 *	-
A1 and D1.	Volts	350	300 *	-
*Modulator. (for cut-off)	Volts	-115	-80	-45
D2)	Volts	-	600	-
D3) Max interstage	Volts	-	800	-
D4) voltage 350V	Volts	-	1000	-
D5)	Volts	-	1200	-
Anode)	Volts	1350	1250	-
Heater voltage	Volts	6.8	6.3	5.8
Heater current	Amperes		0.6	
Peak heater cathode voltage	Volts	10		-125
Capacitance of anode to all.	pf		12	
Anode current	Microamperes		30	
Signal output current (p-p)	"		1 to 15	
Ratio p-p highlight signal-current to r.m.s. noise current			35	
Peak to peak blanking voltage	Volts	-	-	5
Target temperature	oC	50	35 to 45	35
Temperature difference between target and hotter part of bulb	oC	5		

* A1 300V. Target -3 to 5V with blanking off. All voltages with respect to thermionic cathode.



FIELD STRENGTH AT CENTRE OF FOCUSING COIL 75 GAUSS

FIELD STRENGTH OF ALIGNMENT COIL 0 - 3 GAUSS



DIHEPTAL BASE.

PIN	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ELECTRODE	H	A3	A2	I.C.	D2	D4	A	D5	D3	A1,D1	I.C.	M	C	H

I.C. INTERNAL CONNECTION.

H. HEATER. C. CATHODE. M. MODULATOR.

JUMBO ANNULAR. 7 PIN BASE.

PIN	1	2	3	4	5	6	7							
ELECTRODE	A5	P.C.	I.C.	I.C.	A4	T	I.C.							

P.C. PHOTOCATHODE. T. TARGET.

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9564
(see following sheet for 9564, 9565 outline)

VALVE DIVISION

IMAGE ORTHICON CAMERA TUBE TYPE 9564

IO

The 9564 is a 4½ inch Image Orthicon Television camera tube for use in place of type 9565 on outside broadcasts under poor lighting conditions. The tube gives a good signal-to-noise ratio with a scene brightness of 25 foot-lamberts at F5.6 and is stable over a wide range of light levels. The spectral response closely approaches that of the human eye.

The 9564 will operate in place of R.C.A. or E.E.V. type 7295.

CHARACTERISTICS

Mechanical

Average Weight	2 lb 3 oz (1 Kg)
Bulb Diameter:	4.5 ± 0.094 inches
Neck Diameter:	3.125 ± 0.060 inches
Overall Length:	19.375 ± 0.310 inches
Useful size of cathode:	1.6 inches max. diameter.

Electrical (All voltages with respect to cathode except where stated)

	Unit	Max.	Typical	Min.
Photocathode sensitivity	μA/L	-	45	25
P.C. voltage	Volts	-200	-470	-700
P.C. illumination	ft.candles	50	0.04	
Grid No.6 voltage (Accelerator)				
40% to 80% of P.C. voltage	Volts	-	-350	-700
Target cut off voltage (blanking off)	Volts	+5	-2	-3
Target voltage above cut off	Volts		2-3	
Field mesh with respect to G4	Volts	50	15	10
Grid No.5 voltage (Decelerator)	Volts	300	150	0
Grid No.4 voltage (Beam focus)	Volts	350	140	40
Grid No.3 voltage (Multi Focus)	Volts	350	250	150
Grid No.2 voltage (& Dynode 1)	Volts	350	300	250
Grid No.1 voltage (Modulator)	Volts	0	-60	-150
Grid No.1 voltage for cut off	Volts	-45	-80	-115
D2 Max. interstage 350V	Volts		600	
D3	Volts		800	
D4	Volts		1050	
D5	Volts		1250	
Anode	Volts	1350	1300	500
Heater voltage (r.m.s.)	Volts	6.9	6.3	5.7
Heater current (r.m.s.)	Amps.	-	0.6	-
Peak heater/cathode voltage	Volts	+10	0	-125
Capacity of anode to all electrodes	μμF		12	
Anode current	μA	125	40	-
Signal current	μA	60	12	6

Performance

	Unit	Max.	Typical	Min.
Ratio peak highlight signal current to r.m.s. noise	dB		37	35
Drop in Amplitude Response at 400 lines/picture height without aperture correction with respect to black/white signals	dB		5	
Peak to peak blanking voltage	Volts	-	-	5
Target Temperature	°C	50	35 to 45	35
Temperature difference between target and hotter part of bulb	°C	5		
Scene luminance required for acceptable pictures at lens stops f5.6	ft.lamberts	25		

Magnetic fields

Image section in plane of P.C.	Gauss		120	
Scanning section in plane of target	Gauss		70	
Alignment field	Gauss		0 to 3	

Optical - Faceplate

Refractive index 1.5076 (5876Å)
Angle to tube axis 90° ± 1°
Surfaces are parallel within 0.01 inch.
Thickness 0.188 ± 0.015 inches
Spectral response: S10

Warning: Mounting position - any except with diheptal base upwards and with the tube axis at an angle less than 20° to the vertical.

EC8/67-2
27.4.61.

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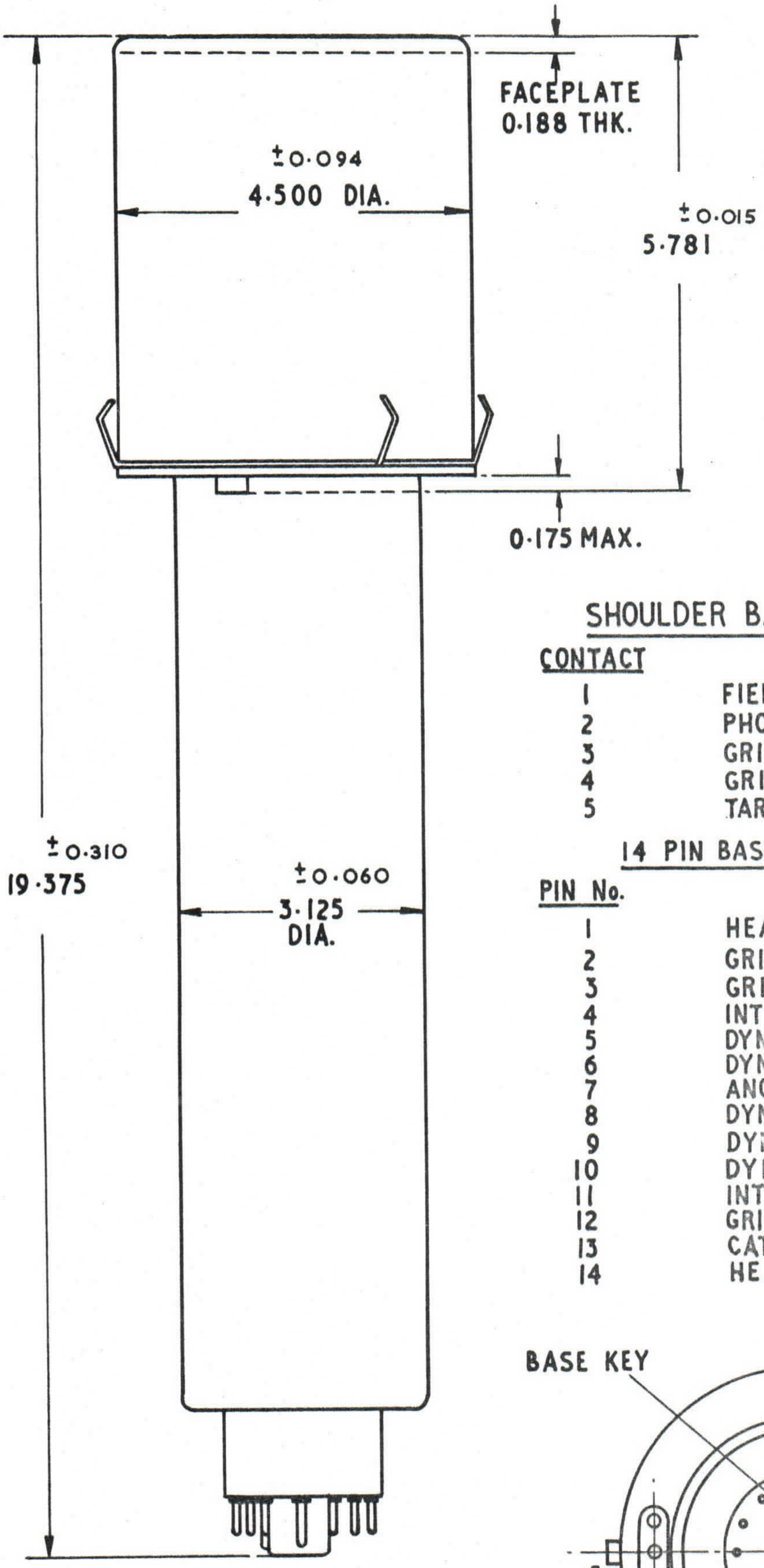
9564
9565

IMAGE ORTHICON CAMERA TUBE TYPE 9564 & 9565.

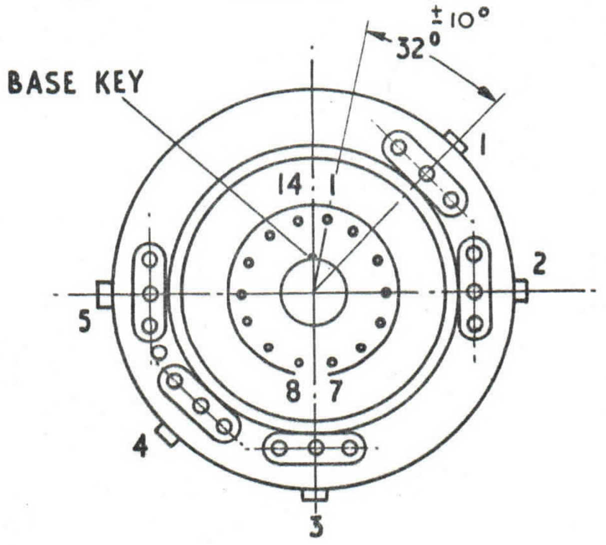


SHOULDER BASE CONNECTIONS

CONTACT	CONNECTION
1	FIELD MESH
2	PHOTOCATHODE
3	GRID No. 6.
4	GRID No. 5.
5	TARGET.

14 PIN BASE CONNECTIONS

PIN No.	CONNECTION
1	HEATER
2	GRID No. 4.
3	GRID No. 3.
4	INTERNAL CONNECTION - DO NOT USE.
5	DYNODE No. 2.
6	DYNODE No. 4.
7	ANODE
8	DYNODE No.5.
9	DYNODE No.3.
10	DYNODE No.1. GRID No.2.
11	INTERNAL CONNECTION - DO NOT USE.
12	GRID No.1.
13	CATHODE
14	HEATER



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EMI HIGH RESOLUTION VIDICON TYPE 9677

The EMI High Resolution Vidicon type 9677 has been designed for use in studio broadcast television cameras and in high quality industrial television cameras The 9677 has the latest separate mesh electrode structure and a very uniform target layer. This has resulted in a vidicon with excellent signal uniformity over a wide range of target voltages and an exceptionally high resolution capability.

An important feature of the 9677 vidicon is its ability to operate at high beam currents and low target voltages without loss of picture quality.

The low heater wattage (0. 6W) of the 9677 makes it very suitable for use in transistorised cameras and in cameras where heat dissipation must be kept to a minimum.

DATA

GENERAL

Scanned Area	12. 8 mm x 9. 6 mm ($\frac{1}{2}$ in x 3/8 in)
Length	158. 75 ± 3. 30 mm (6. 25 ± 0. 130 in)
Max. Diameter	28. 58 ± 0. 20 mm (1. 125 ± 0. 008 in)
Bulb Diameter	25. 91 ± 0. 64 mm (1. 020 ± 0. 030 in)
Focusing Method	Magnetic
Deflection Method	Magnetic
Alignment Method	Magnetic
Orientation of Image	The horizontal scan should be parallel to a plane passing through the tube axis and the short index pin.
Signal Electrode Capacitance to all other electrodes	4. 5 pF
Spectral Response	See fig. 2.
Operating Position	Any (see note 1)
Socket	Small-Button Ditetrar 8 pin.

CATHODE

The heater supply should be designed to give a nominal 6. 3 V and should be kept within the limits 5. 7 V to 6. 9 V. Under no circumstances should the heater voltage be allowed to exceed 9. 5 V, if this figure is likely to be exceeded on switching on a surge limiting device must be incorporated.

MAXIMUM RATINGS

(All potentials are relative to the cathode)

Modulator G1 negative bias	-150 V
positive bias	0 V
Limiter G2	750 V
Wall anode G3	750 V
Mesh G4	1000 V
Signal Electrode Voltage	100 V
Dark Current	0.6 µA
Target Illumination	10000 lux
Target Temperature	70°C

These maximum ratings are limiting values above which the life of the tube may be impaired.

TYPICAL OPERATING CONDITIONS

Modulator G1	-35 to -75 V
Cut off Voltage	-60 to -100 V
Limiter G2	300 V
Wall Anode G3	280 to 300 V
Mesh G4	420 to 450 V
Minimum blackout pulses when applied to G1	-75 V
Minimum blackout pulses when applied to cathode	+10 V
Axial Magnetic Field	40 gauss
Adjustable transverse alignment field	± 4 gauss

STUDIO OPERATION

Target illumination (Highlights)	6 ft. C.
Signal Electrode Voltage	25 - 40 V
Dark Current	<0.01 µA
Signal Current	0.25 µA to 0.3 µA

INDUSTRIAL OPERATION

Target Illumination (Highlights)	2 ft. C.
Signal Electrode Voltage	30 - 60 V
Dark Current	0.01 µA
Signal Current	0.2 µA peak

FILM PICK-UP OPERATION

Average highlight for one frame	50 - 100 ft. C
Signal Electrode Voltage	10 - 20 V
Dark Current	<0.005 µA
Signal Current	0.25 - 0.30 µA

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LEAKAGE SPECIFICATION

Between Pin No.	and Pin No.	Test Potential	Leakage Current
2, 3, 5, 6, 7,	1 and 8 (negative)	100 V	100 μA Max.
1, 3, 5, 6, 7, 8,	2 (negative)	150 V	15 μA Max.
1, 2, 3, 6, 7, 8,	5 (positive)	500 V	50 μA Max.
1, 2, 3, 5, 7, 8,	6 (positive)	500 V	5 μA Max.
1, 2, 5, 6, 7, 8, and signal plate	3 (positive)	500 V	5 μA Max.

OPERATING NOTES

1. Resolution

For optimum resolution and beam landing at a given wall anode voltage the mesh should be kept at approximately 1. 5 times the wall anode voltage. Under these conditions the percentage modulation at 5 Mc/s on a 625 line system is double that of a normal vidicon and the scanning current has only to be increased by approximately 20%. From fig. 3 it can be seen that an appreciable increase in depth of modulation can be obtained when the mesh is only a few volts positive to the wall anode and under these conditions negligible increase in scanning current is required.

The resolution can be further increased by increasing the wall anode voltage and the corresponding mesh voltage, but this will require additional focus current and scan power (see fig. 4). To operate the 9677 in a standard camera the mesh should be connected to the limiter by joining pin 3 (mesh) to pin 5 (limiter) provided the limiter is positive with respect to the wall anode.

On no account should the mesh be operated at a lower voltage than the wall anode since, under these conditions, an ion spot may be observed.

The increased vertical resolution obtained with a 9677 vidicon will give an obvious increase in picture sharpness compared with a standard tube since the relatively poor vertical resolution of a standard tube cannot be corrected by aperture correction.

The increased horizontal resolution of the 9677 compared with the standard tube (see fig. 4) enables aperture correction in the head amplifier to be reduced, with corresponding increase in signal to noise ratio. If the 9677 is being fitted into a standard camera and the aperture correction is not reduced, high frequency "ringing" may occur.

2. Beam

The setting of the beam current in the 9677 is less critical than with a standard vidicon provided the mesh is positive with respect to the wall anode. The 9677 can be over-beamed without loss of resolution, thus the beam can be preset to discharge the peak highlights, no further adjustment being required.

Beam landing is considerably improved as the mesh voltage is increased to the optimum of 1. 5 times the wall anode voltage. Under these conditions the "porthole effect" which occurs at low target voltages is eliminated.

Rotation of the picture when the wall anode is varied about electrical focus is considerably reduced when the mesh is at least 20 volts or more positive with respect to the wall anode.

3. Sensitivity

The uniform target layer of the 9677 ensures that when the target voltage is increased the dark current and sensitivity increase uniformly over the target area.

The dark current should not, however, be allowed to exceed 0.6 μA or a burnt-in picture may result.

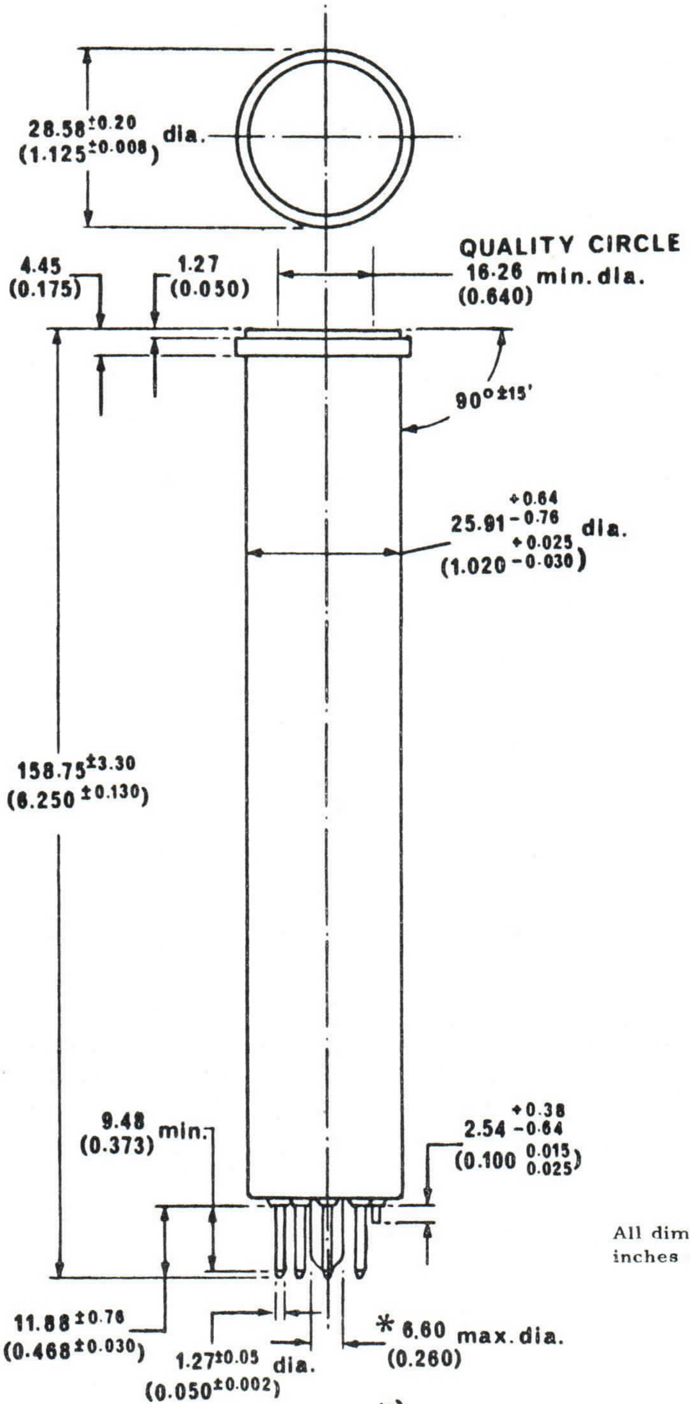
4. Scanned Area

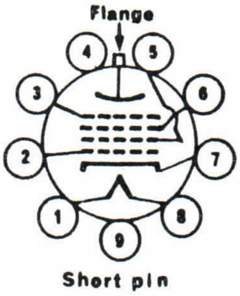
The tube should be operated with the target area 12.8 mm x 9.6 mm ($\frac{1}{2}$ in x 3/8 in) completely scanned to obtain the best signal to noise ratio and resolution. Small changes in sensitivity and dark current occur in the scanned area over a long period of time so that it is important to use the same scanned area throughout the life of the tube.

5. Operating Position

When the 9677 is operated vertically with its face downwards care should be taken to avoid undue mechanical shock.

EMI VIDICON CAMERA TUBE TYPE 9677





BASE 8HL
SMALL BUTTON DITETRAR

Pin No.	Connections
1	Heater
2	Modulator G_1
3	Mesh G_4
4	Do not use
5	Limiter G_2
6	Wall anode G_3
7	Cathode
8	Heater
Flange	Signal electrode
Short pin	Do not use

All dimensions are in millimetres with inches shown in parentheses.

*) Seal-off must not extend beyond pins.

FIGURE 1

T413/5b
DS. 318/5

RELATIVE SPECTRAL RESPONSE

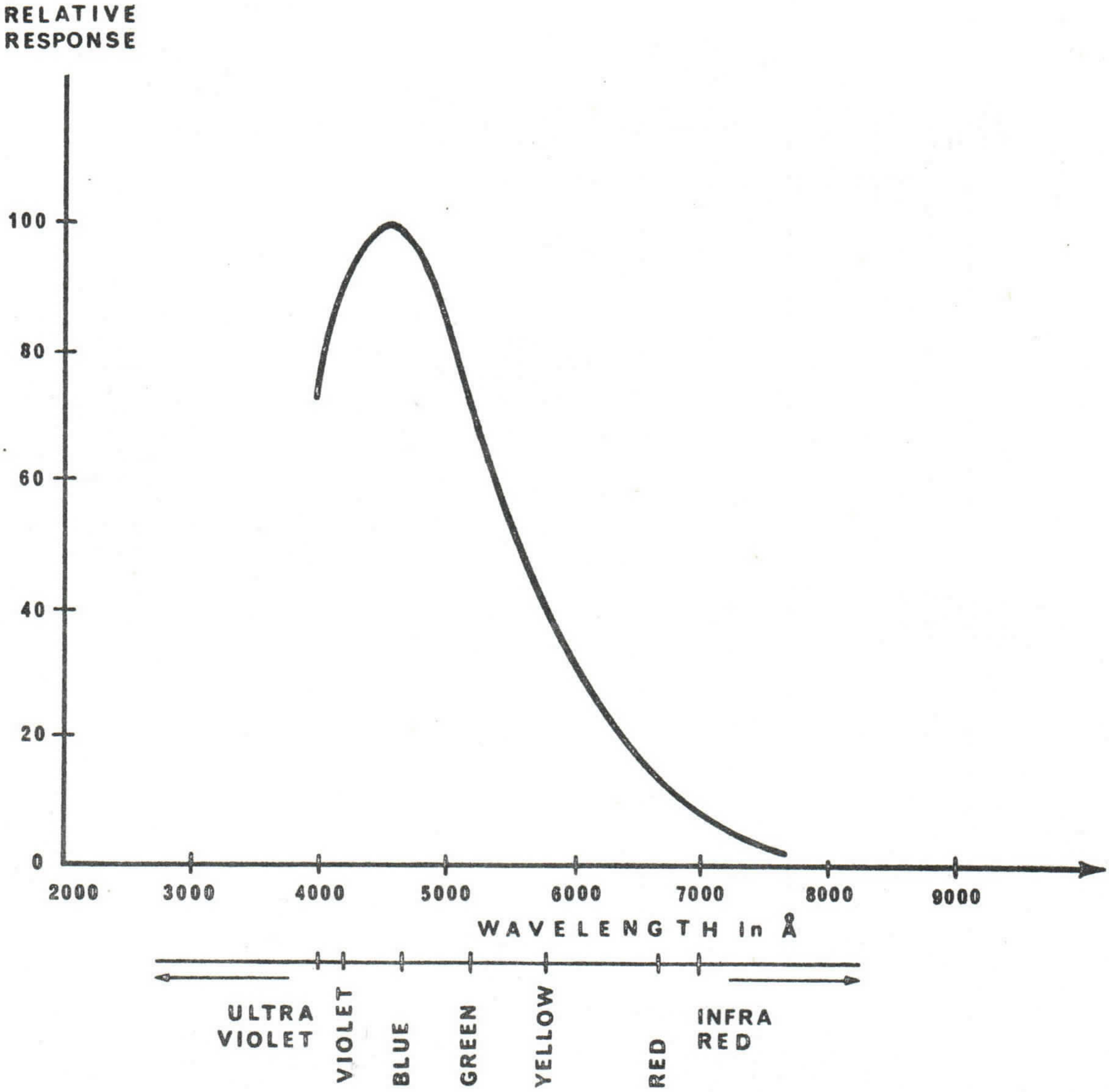


FIGURE 2

T413/6b
DS. 318/6

TYPICAL DISCONTINUITY IN MODULATION CURVE

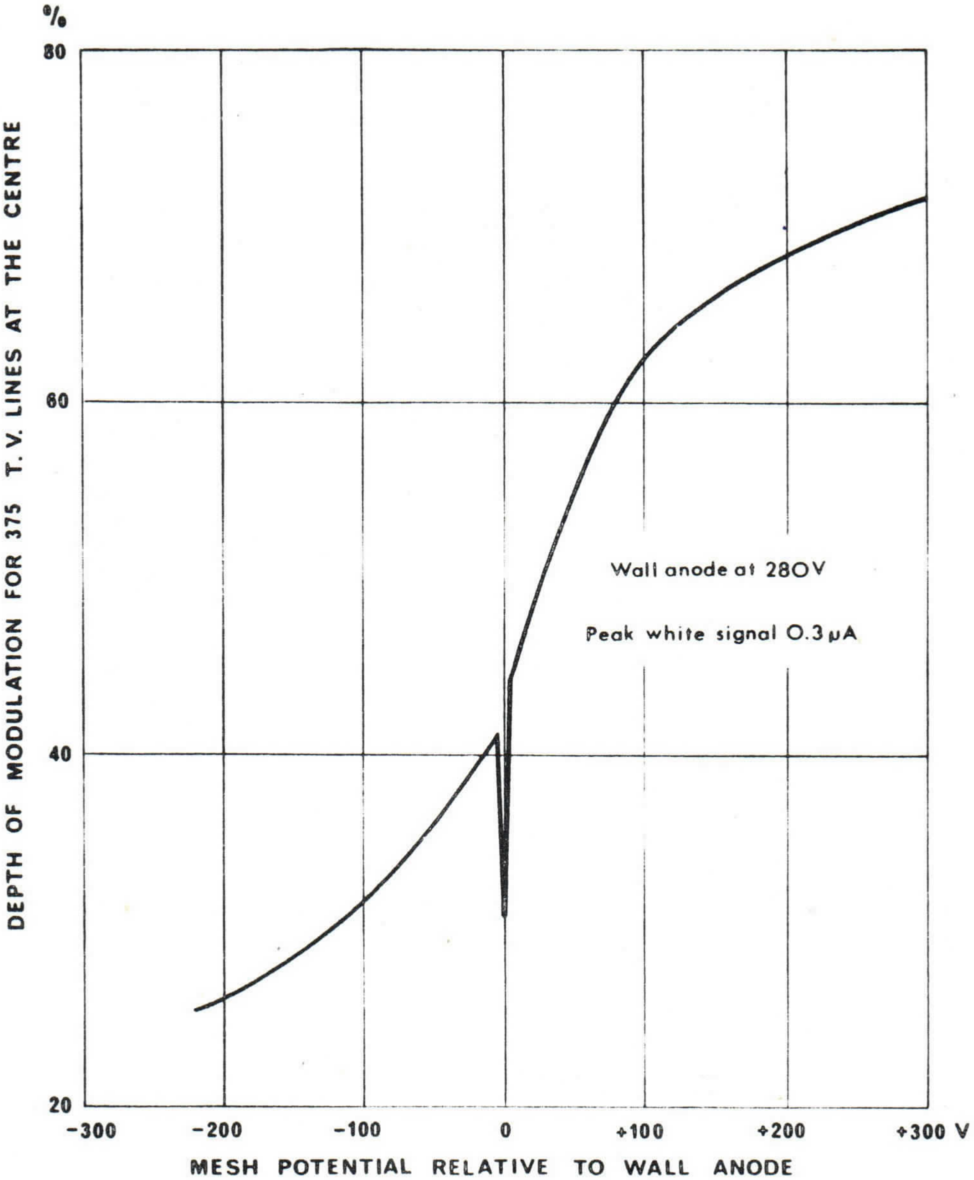


FIGURE 3

T413/7b
DS. 318/7

TYPICAL RESOLUTION CHARACTERISTICS

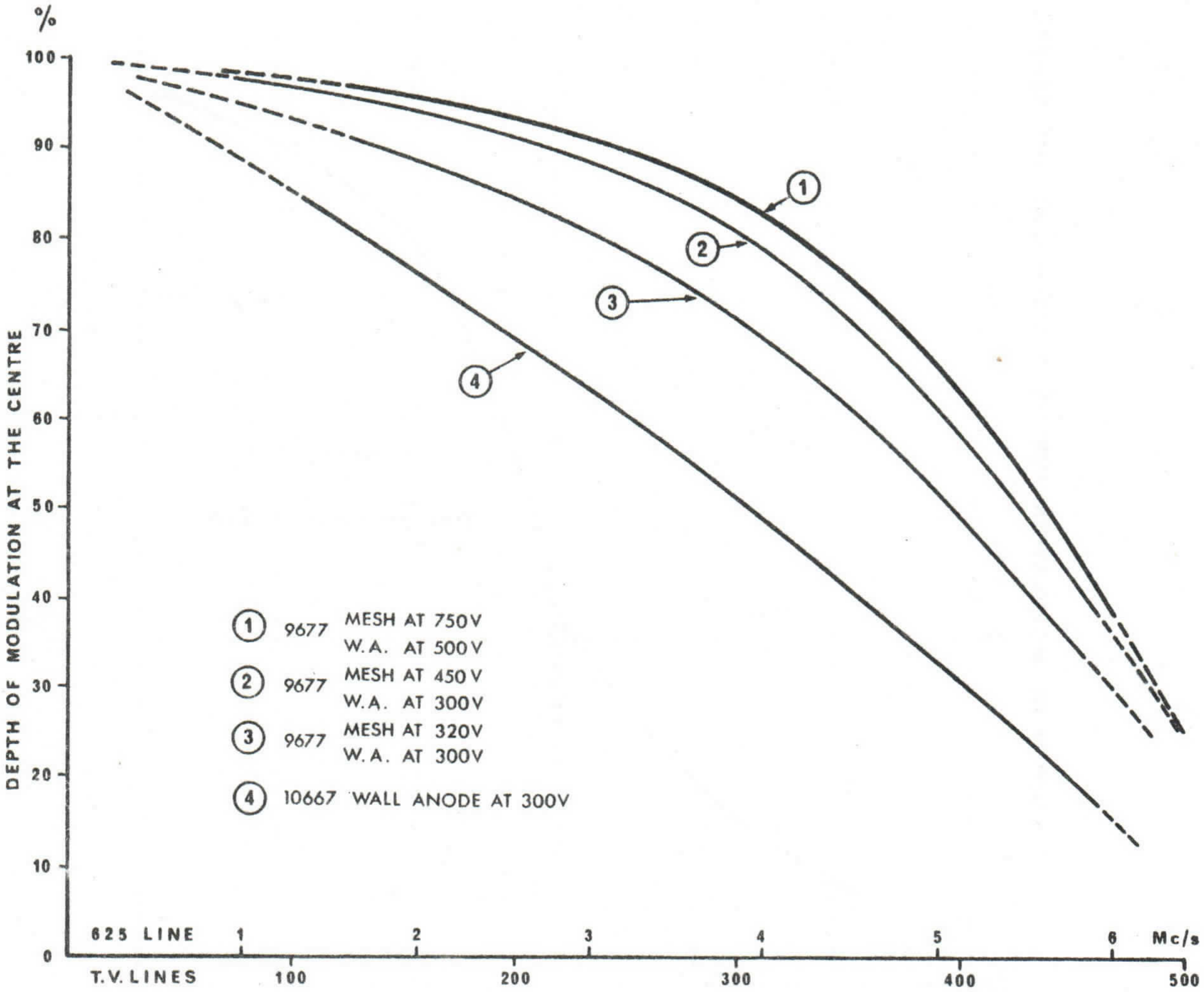


FIGURE 4

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VALVE DIVISION New Product Data

EMI HIGH RESOLUTION VIDICON TYPE 9728

(Preliminary specification)

To meet the requirements of a high quality separate mesh one inch Vidicon for use in cameras employing a 0.3 A series heater chain, EMI have introduced a 6.3 V, 0.3 A heater version of the separate vidicon type 9677. The type number of this new tube is 9728 available in the same grades as the 9677 i.e. 9728B, 9728C etc.

Should the tube type 9728 be required for use in a 0.6 A heater chain then the 9728 heater must be shunted by two 43 Ω, 1 W, 5% resistors connected in parallel.

When not used in a series heater chain the heater supply should be designed to give a nominal 6.3 V and should be kept to the limits 5.7 V to 6.9 V. If this figure is likely to be exceeded on switching on a surge limiting device must be incorporated.

Apart from the heater wattage the 9728 is similar to the 9677 in all respects.

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VALVE DIVISION

Preliminary Data Sheet.

RUGGED VIDICON TYPE 10667J (VX5093).

This is a 1" photoconductive camera tube having standard dimensions and similar externally to E.M.I. Industrial Vidicon type 10667G. The electrical characteristics, sensitivity and lag, etc. are also similar to the 10667G. Internally, however, a rugged structure has been developed which enables this tube to operate in adverse environmental conditions, at any orientation.

The vibration characteristics are as follows :- Over the frequency range of 30 to 3000 cps, with a peak acceleration of up to 10g, in a specified mounting, the deviation at any point of the scan will be less than 1/3rd line spacing.

EC8/14
28.4.60.

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EMI STORAGE VIDICON CAMERA TUBE TYPE 10667L

EMI vidicon tube type 10667L is a standard one inch vidicon camera tube with a special photoconductive target. This target has a long photoconductive lag in addition to a long capacitive lag.

A vidicon tube has a transparent conducting layer on the inside of the end window, which acts as the signal plate. The photoconductive target is applied to this signal plate and a low velocity electron beam scans the inside surface of this target. The action of scanning stabilizes this surface to the electron gun cathode potential. The signal plate is maintained at several volts positive to this potential, so that a potential difference is set up across the photoconductive target.

In the absence of light the photoconductive target is a good insulator, but when light falls on a part of the target it's resistance falls and a more conductive path is established; current flows across this path and the potential of the inner surface of the illuminated area rises towards signal plate potential. When the beam scans this area it reduces the potential towards gun cathode potential causing a signal current to flow in the signal plate by capacitive coupling. Because of the large capacity of the 10667L tube target the beam cannot reduce the potential to cathode potential in one scan. This gives rise to capacitive lag.

When the illumination is removed from the photoconductive target in a normal vidicon tube, the area which was illuminated rapidly becomes a good insulator once more, but in the special target of the 10667L tube the photoconductive target takes a considerable time to reach this state. This is known as photoconductive lag.

The two lag effects which have been described above, together give a storage picture which slowly fades after the illumination has been removed. Depending on the operating potentials the stored picture reaches a low level in a period of one to three minutes.

The use of a special photoconductive camera tube as a storage tube was first developed by The Research Laboratories, EMI Ltd.* Using tubes of a larger diameter than the 1 inch vidicon storage times of up to 15 minutes have been achieved.

Since the EMI tube 10667L is a standard size it can be fitted into a standard industrial camera thus providing a storage camera channel at low cost. There is a steadily increasing demand for storage cameras in such applications as scan conversion systems, such as obtaining a television picture of a radar P.P.I. scan. Another application is the storage of single transients for a limited period.

* Some Half-Tone Charge Storage Tubes by R.S. Webley, H.G. Lubszynski and J.A. Lodge Proc. I.E.E. Vol 102 Part B No.4 July, 1955.

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EMI VIDICON CAMERA TUBE TYPE R9620

Provisional Data

The EMI R9620 is a low heater-wattage Vidicon (0.6W) designed specifically for use in transistorised cameras. This tube which employs a uniform high-sensitivity prefabricated target layer of substantially panchromatic response is intended for use in Industrial and Broadcast Television Camera Channels.

The tube has been designed to operate in any position. It has an envelope without side pip to make possible the use of longer deflection coils, and to reduce the risk of damage when handling.

The type suffixes for different grades of the R9620 are as follows:-

R9620	Industrial Grade
R9620F	Film Grade
R9620S	Studio Grade

CHARACTERISTICS

General

Scanned Area	12.8 mm x 9.6 mm (½" x ⅜")
Focussing Method	Magnetic
Deflection Method	Magnetic
Alignment Method	Magnetic
Orientation of Image	The horizontal scan should be parallel to a plane passing through the tube axis and the short index pin.

Cathode

Heater Voltage	6.3 V
Heater current	95 mA ± 10%

The heater supply should be designed to give a nominal 6.3 V, and should be kept within the limits 5.7 to 6.9V.

Maximum Ratings

All potentials are relative to the cathode.

Signal Electrode	100 V
Modulator G1 negative bias	-150 V
positive bias	0 V
Limiter G2	350 V
Wall Anode G3	800 V
Dark Current	0.6 μA
Target illumination	10,000 lx
Target temperature	60 °C

These maximum ratings are limiting values above which the life of the tube may be impaired.

TYPICAL OPERATING CONDITIONS

Modulator G1 (300 V limiter)	-35 to -75 V
Cut off voltage (300 V limiter)	-60 to -100 V
Limiter G2	300 V
Wall Anode G3 (with 40 gauss focus field)	275 to 295 V

Performance

Illumination	20 lx (2 f.e.)
Dark current	0.01 μA
Signal current	0.15 μA
Signal volts	25 to 60 V

Black out pulses

When applied to modulator (G1)	-85 V min.
When applied to cathode	+10 V min.
Axial magnetic field	40 gauss
Adjustable transverse alignment field	±4 gauss
Signal electrode Capacitance	
a) to all other electrodes	4.5 pF
b) to earth (with tube in EMI studio scanning coils)	9.5 pF

The R9620 can be used as a direct replacement for the following types:-

R9620	55850N
R9620F	55850F
R9620S	55850S

The R9620 can also be used as a replacement for any standard 25.4 mm (1 in) vidicon provided the correct heater ratings are observed.

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Hayes Middlesex England *(Controlled by Electric & Musical Industries Limited)*

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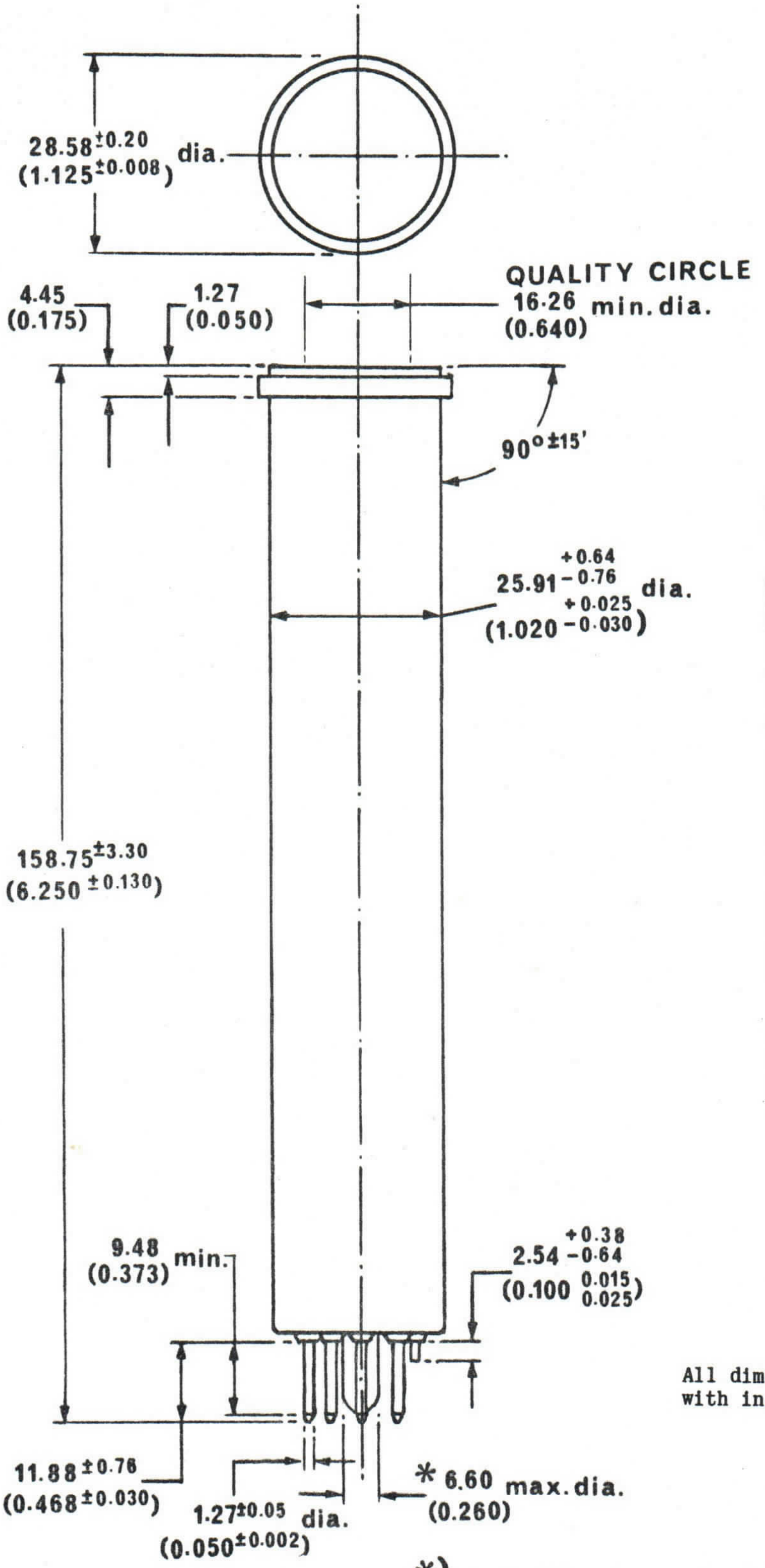
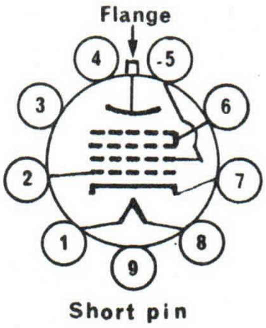
EMI VIDICON CAMERA TUBE TYPE R9620





BASE 8HL
SMALL BUTTON DITETRAR

Pin No.	Connections
1	Heater
2	Modulator G_1
3	Do not use
4	Do not use
5	Limiter G_2
6	Wall anode G_3 , G_4
7	Cathode
8	Heater
Flange	Signal electrode
Short pin	Do not use

All dimensions are in millimetres
with inches shown in parentheses.

*) Seal-off must not extend beyond pins

FIGURE 1

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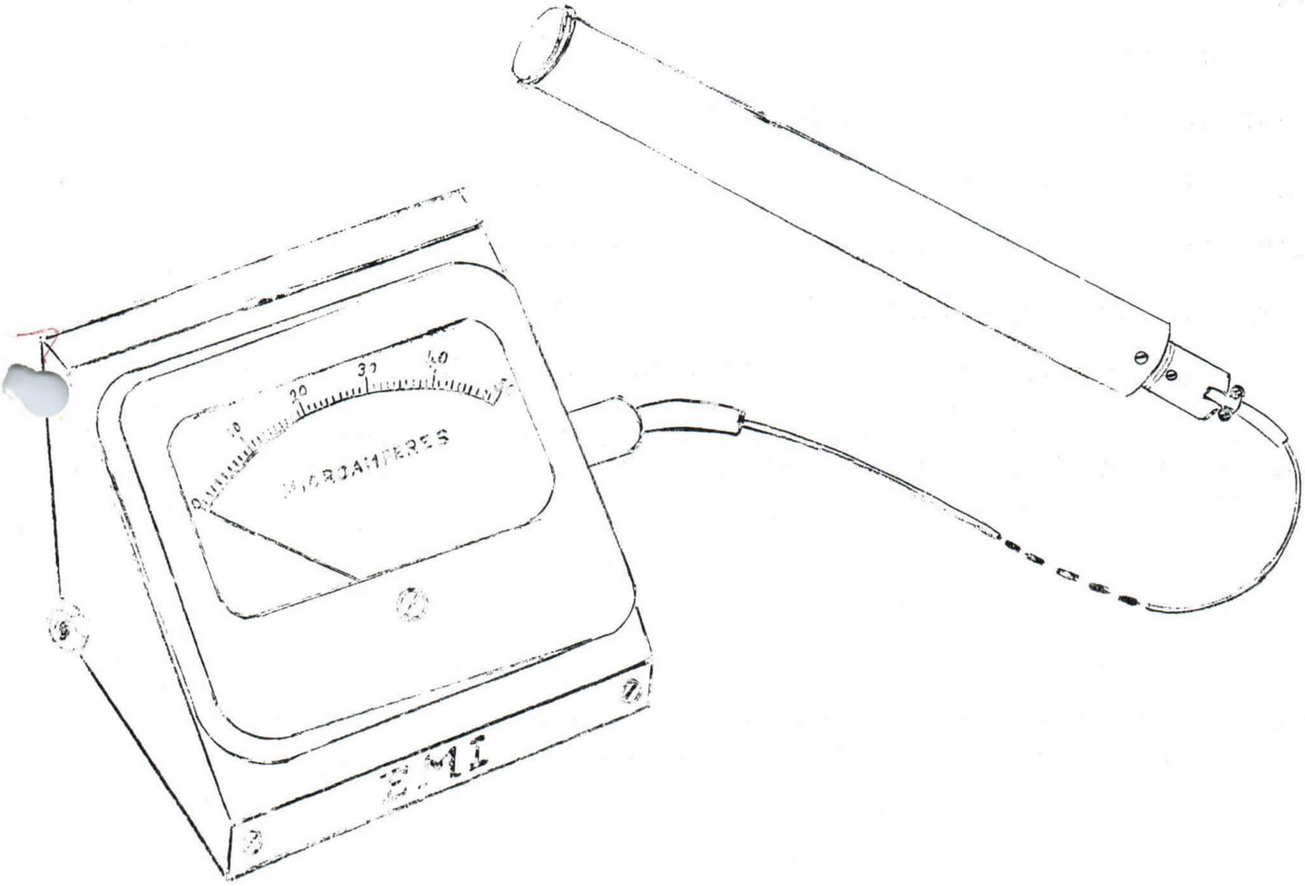
VIDICON TARGET ILLUMINATION PHOTOMETER



This instrument has been designed to avoid the difficulty in setting the light intensity to its correct value in Vidicon Telecine equipment. It consists of a selenium photovoltaic cell mounted in a dummy vidicon tube, which is connected via a length of cable to a microammeter. (See illustration).

The dummy tube is mounted in the deflecting coils in place of the normal vidicon tube, and the meter gives a substantially linear indication of the target illumination. An individual calibration curve is provided on the back of the meter case.

/continued ...

DATA

Length of meter scale	approx.	$3\frac{1}{2}$ inches
Full scale deflection	"	200 Foot Candles
Colour temperature used in calibration		2854^{o}K
Length of connecting cable		6 feet
Connection to dummy vidicon	via 2 pin plug	
Connection to meter case	via jack plug	

(A jack socket is provided on both sides of the meter case)

Dimensions of dummy vidicon as for E.M.I. tube type 10667.

NOTE : For correct calibration both dummy vidicon and meter case must have the same serial number.

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TDX3

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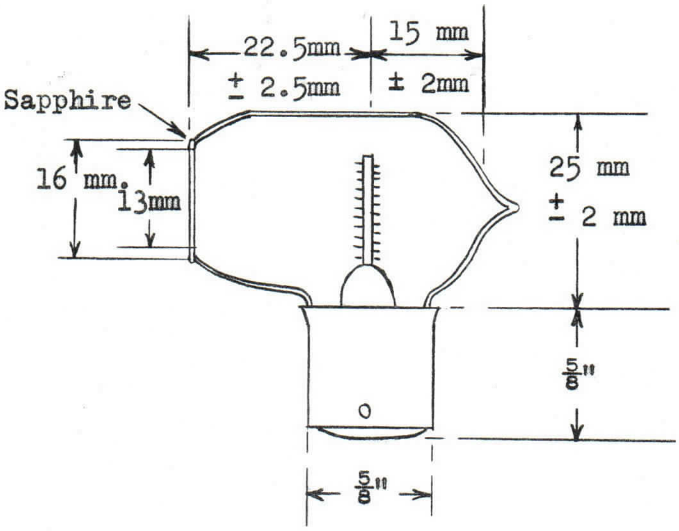
I. R. SOURCE TDX3

(Provisional Data).

Envelope



Sapphire Window	-	16 mm. dia. 0.75 mm. thick.
Source Size	-	$\frac{1}{4}$" x 0.030" O/D coil 28 turns of 0.005" dia. Tungsten wire.
Supply	-	12 V.A.C. 3 amps ≏ 36 watt.
Cap	-	2 contact type S.B.C. without flare $\frac{5}{8}$" long, $\frac{5}{8}$" dia.
Transmission of Sapphire Window	-	80% at 5.5 μ 50% at 6.25 μ 20% at 6.75 μ
Included Gas	-	Argon at 5 cm. of Hg pressure.

EC8/60
10.3.61.

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Corona Stabilisers

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VALVE DIVISION

CORONA STABILISERS

The corona stabiliser is particularly suitable for stabilising Geiger counter or photomultiplier supplies but can also be used for stabilising beam focussing and accelerating potentials of cathode ray devices. It may also be used as a general purpose voltage reference tube for all electronic equipment.

Type	Stabilised Output Voltage		Base
	*Nominal (V)	Actual (V)	
SC 1/350	350	335-365	B7G
SC 1/400	400	380-420	B7G
SC 1/600	600	580-620	B7G
SC 1/800	800	780-820	B7G
SC 1/1000	1000	975-1025	B7G
SC 1/1200	1200	1170-1230	B7G
SC 1/1400	1400	1365-1435	B7G
SC 1/1600	1600	1560-1640	B7G
SC 1/1800	1800	1755-1845	B7G
SC 1/2000	2000	1950-2050	B7G
SC 3/350	350	335-365	Wire Ended
SC 3/400	400	380-420	Wire Ended
SC 4/5000	5000	4800-5200	B9A
SC 4/6000	6000	5800-6200	B9A
SC 4/7000	7000	6800-7200	B9

SC 3

The striking voltage is approximately 50V in excess of the operating voltage.

* Tubes may be supplied at any other voltage within the range, subject to a minimum order for 50 tubes.

TUBE IMPEDANCE

In general the stabilized voltage will not vary by more than ± 0.25% for a ± 10% change in tube current.

STABILITY

The variation of operating voltage of a tube measured at a given current over thousands of hours is likely to be about 1%.

TEMPERATURE STABILITY

The variation of operating voltage with temperature is of the order of 0.01% per °C.

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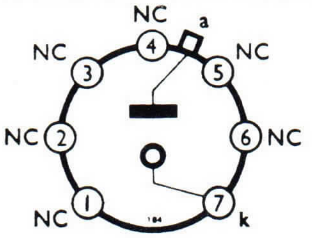
SC1 Series
CORONA STABILISERS

The corona stabiliser is particularly suitable for stabilising Geiger counter or photomultiplier supplies and it can also be used for stabilising the focusing and accelerating potentials of cathode ray tubes. It is also useful as a general purpose reference tube.

BASE CONNECTIONS AND VALVE DIMENSIONS



View from underside of base

Base : B7G
Bulb : Tubular
Max. overall length : 72.5mm.
Max. diameter : 19 mm.
Top cap : CT1

This series of gas discharge stabilisers provides a stabilised voltage (V_{stab}) over the range 350-2000V (depending upon the type) at an operating current of a few hundred microamperes. The striking voltage is approximately 50V in excess of the operating voltage and the a.c. resistance is of the order of 50kΩ.

CHARACTERISTICS

Stabilised Output Voltages

The actual stabilised voltage (measured at a tube current of 250μA) from any particular tube will be within the ranges given.

SC1/350 :	335-365V	SC1/1200 :	1170-1230V
SC1/400 :	380-420V	SC1/1400 :	1365-1435V
SC1/600 :	580-620V	SC1/1600 :	1560-1640V
SC1/800 :	780-820V	SC1/1800 :	1755-1845V
SC1/1000 :	975-1025V	SC1/2000 :	1950-2050V

Tubes are supplied to give any other voltage in the range 350-2000V in minimum quantities of 50.

Stable Current

Minimum : 20μA
Maximum : 750μA (600μA for SC1/350

Stability

The variation in stabilised voltage at a given current is likely to be about 1% over several thousand hours. (2% in the case of the SC1/350).

Temperature Stability

The variation in stabilised voltage is of the order of 0.01% per °C.

Impedance

The stabilised voltage will not vary by more than ±0.25% for a ±10% change in tube current from 250μA, except for the SC1/350 and SC1/400 tubes which will not vary by more than ±0.5% for a ±10% change in tube current from 250μA.

OPERATION

The stabilising ratio is : $\frac{r}{R_L + r} = \frac{V\ out}{V\ in}$

where r = a.c. tube resistance, and R_L = tube series resistor : i.e. if $R_L = 10M\Omega$ a ratio of about 0.5% is obtained

The voltage drop across R_L must be considered when calculating the required supply voltage (V_{in}). Thus, assuming R_L to be $10M\Omega$, then for a tube with $V_{stab} = 400$ and a total current ($I_{tube} + I_{out}$) of $50\mu A$, V_{in} must be 900V. See fig. 1.

The maximum and minimum values of V_{in} are determined by the maximum and minimum tube currents for stable operation.

The corona stabiliser may be incorporated in a valve circuit to provide a stabilised voltage at a higher current than is possible with the tube alone. A suggested cathode follower circuit is given in fig. 2. In this case the stabilising ratio is :

$$\frac{r}{R_L + r} + \frac{I}{\mu}$$

where μ is the amplification factor of V1. It follows that, using a tube with a normal value of $r = 50k\Omega$ and with an R_L of $2M\Omega$, a valve with a relatively high μ is required if a satisfactory stabilising ratio is to be obtained and this limits the circuit to currents not greatly exceeding 10mA. A triode-connected Z77 has been found satisfactory.

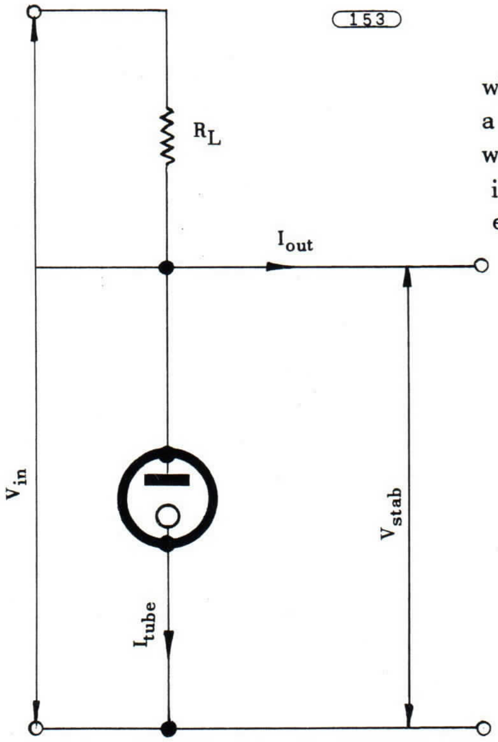


Fig. 1. (Above).

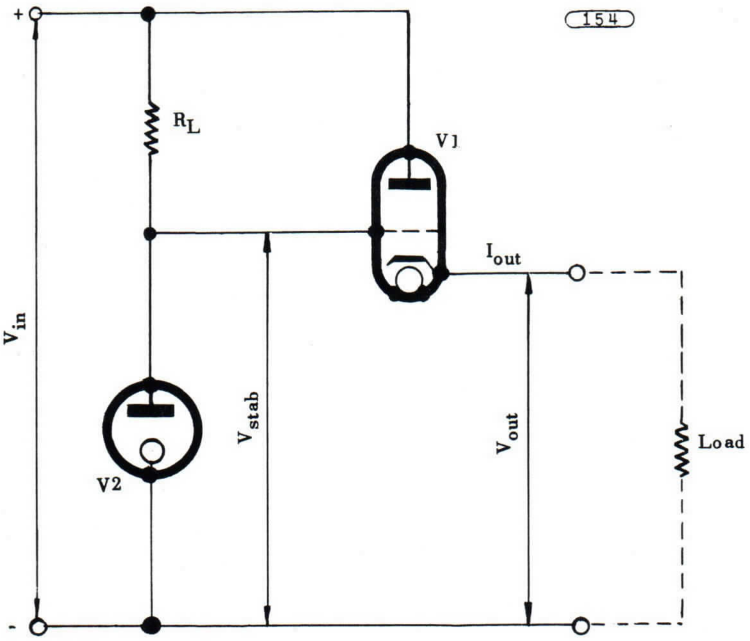


Fig. 2. (Right).

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SC3 Series

CORONA STABILISERS

Base : Flying Lead
Bulb : Tubular

Dimensions

Overall length : 60 mm Max.
Max. diameter : 12 mm

Leads

Cathode : Black
Anode : Red

This design of gas discharge tube is made for operation at a stable voltage in the range 350 to 2000 volts with an operating current of the order of a few micro-amps.

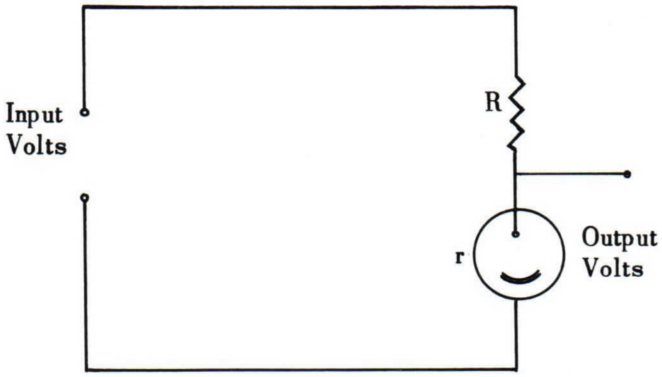
The gas discharge is in the corona region and in operation the tube has an A.C. resistance of the order of 60,000 ohms.

The stabilising ratio is :

$$\frac{r}{R + r} = \frac{dV\ out}{dV\ in}$$

r = the A.C. resistance of the stabiliser
R = value of the series resistance

i.e. If R = 10 megohms a stabilising ratio of approximately 0.5% is obtained.



Account must be taken of the voltage drop across R in deciding what E.H.T. supply is needed for a stabiliser with a given stabilising ratio and operating voltage V_0.

Thus for a tube with V_c = 400V, and a total current in the tube and output circuit of $50/\mu A$, an E.H.T. supply of 900 volts will be required, assuming R = 10 megohms.

The maximum and minimum values of E.H.T. are set by the maximum and minimum current for stable operation of the corona tube.

The tubes which are hydrogen filled have their operating voltages determined by the hydrogen pressure.

The Corona stabiliser is particularly suitable for stabilising Geiger counter or photo multiplier supplies but can also be used for stabilising beam focussing and accelerating potentials of cathode ray devices. It may also be used as a general purpose reference tube for all electronic equipment.

The tube is essentially a smaller version of the SC1 and is designed for use at a lower operating current.

STABILISED VOLTAGE OUTPUTS

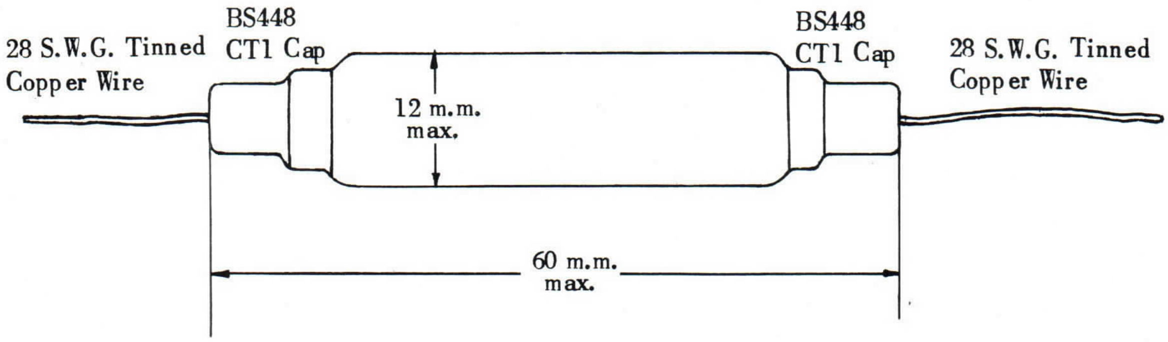
Type	Stabilised Output Volts	
	Nominal	Actual
SC3/350	350	335 – 365
SC3/400	400	380 – 420
SC3/600	600	580 – 620
SC3/800	800	780 – 820
SC3/1000	1000	975 – 1025
SC3/1200	1200	1170 – 1230
SC3/1400	1400	1365 – 1435
SC3/1600	1600	1560 – 1640
SC3/1800	1800	1755 – 1845
SC3/2000	2000	1950 – 2050

The striking voltage is approximately 50 volts in excess of the operating voltage.

CHARACTERISTICS

Stabilising Voltage	The stabilising voltage is measured at 15 μA.
Stable Current	5 μA Min. 50 μA Max.
Tube Impedance	Approximately 60,000 ohms.
Temperature Stability	The variation of operating voltage with temperature is of the order of 0.01% per °C.

S.C.3



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SC4 Series

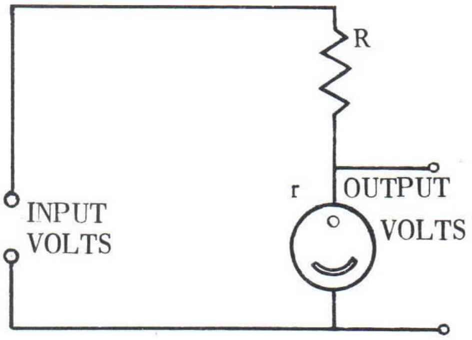
HIGH VOLTAGE CORONA STABILISERS.

These tubes are hydrogen filled gas discharge devices, designed to operate at a stable voltage in the range 4.5 – 7 kV at currents up to about 1.0 mA. The preferred values of normal voltages are 5,6 and 7 kV. Tubes can be supplied to give any other voltage in the range 4.5 – 7 kV in minimum quantities of 10 per voltage.

Stabilising ratio if :–

$$\frac{r}{R + r} = \frac{dV\ out}{dV\ in}$$

Where r = A.C. resistance of the stabiliser
R = value of the series resistance.



Base Connections
Pin 1 – Cathode
Top Cap – Anode

Base :- B9A

Dimensions

Overall length – 82 mmA.
Max. diameter – 22 mmμ.

		SC4/5kV	SC4/6kV	SC4/7kV
Stabilised Output Volts	Nominal	5000	6000	7000
Stabilised Output Volts	Actual	4875 – 5125	5850 – 6150	6825 – 7175
Stable current	Minimum	50μA	50μA	50μA
Stable current	Maximum Continuous Current	1.0mA	1.0mA	1.0mA
Stable current	Peak	2.0mA	2.0mA	2.0mA
Tube Impedance	Measured over current range 0.1 – 0.4 mA.	250K	250K	250K

The Stabilising voltage is measured at 300μA.

Stabilisers should only be operated at the peak current rating for short periods of time. Sustained operation at peak currents may result in the mode of discharge changing from the corona to the glow. This will cause an abrupt reduction in the voltage across the stabiliser with a consequent substantial increase in current.

The tube impedances quoted are approximate values for slow changes in current. For rapid changes, e.g. 5 c.p.s. the values are likely to be approximately doubled. The impedance decreases with increasing current.

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Photomultipliers

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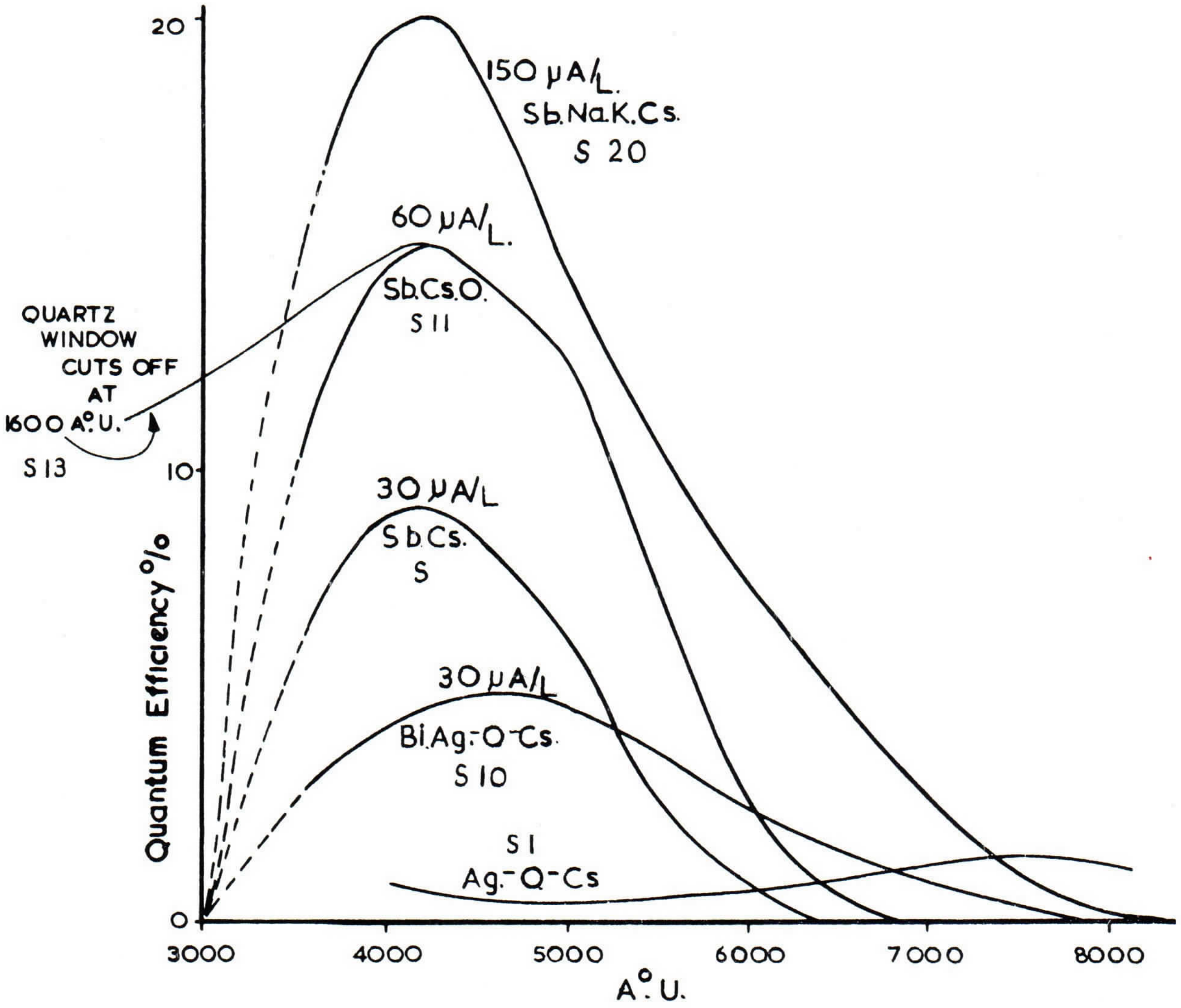
MULTIPLIER PHOTOTUBES FOR SPECTROPHOTOMETRY

Type	Dynodes	Window		Type	Cathode	Sens'y. µA/L.		Average Characteristics			
		Glass	Dia. mm.		Dia. mm.	Min.	Av.	200A/L		2000A/L	
								Volts kV	Dark Current µA	Volts kV	Dark Current µA
6255B	13.V	Quartz.	51.5	S13	44	40	70			1.5	0.3
6255S	"	"	"	S	44		40			1.7	0.03
6256B	"	"	"	S13	10	40	70			1.5	0.03
6256S	"	"	"	S	10		40			1.7	0.005
9552B	10.V	"	"	S13	44	40	70	1.7	0.04		
9552S	"	"	"	S	44		40	1.9	0.005		
9526B	11.B	"	30	S13	23	40	70	1.2	0.02	1.7	0.2
9529B	"	"	"	S10	23	25	35	1.3	0.08		
9502B	13.V	Pyrex or Soda	51	S11	10	40	70			1.5	0.03
9502S	"	"	"	S	10		40			1.7	0.005
6094B	11.V	Kodial or Soda	"	S11	10	40	70	1.45	0.003		
9536B	10.V	Pyrex or Soda	"	S11	44	40	70	1.7	0.04		
9536S	"	"	"	S	44		40	1.9	0.005		
6097B	11.V	"	"	S11	44	40	70	1.45	0.03	2.0	0.3
6097S	"	"	"	S	44		40	1.55	0.003		
6095B	"	"	"	S10	44	25	35	1.7	0.08		
9554B	10.V	"	"	S10	44	25	35	1.9	0.08		
9553B	10.V*	"	"	S1	44		15				
9580B	11.V*	"	"	S1	10		15				
9524B	11.B	Soda	28.6	S11	23	40	70	1.2	0.02	1.7	0.2
9524S	"	"	"	S	23		40	1.4	0.003		
9528B	"	"	"	S10	23	25	35	1.3	0.08		
9558B	11.V	"	51.5	Tri Alkali	44	100	150	1.7	0.002		

Notes: EMI 'S' cathode is CsSb processed for minimum thermionic emission consistent with peak quantum efficiency of 8 - 10% at ca. 4,200 A.U. S11 cathode is CsSbO, having peak quantum efficiency of 12½ - 15% at 4,200 A.U. S13 is this cathode in quartz, sensitive to ca. 1,650 A.U. in UV and ca. 6,700 A.U. in red. S10 is BiAgO.Cs, sensitive up to ca. 7,800 A.U. Tri Alkali is sensitive up to 8,500 A.U. and has peak quantum efficiency of 12 - 20% at 4,200 A.U. and 4 - 8% at 6,000 A.U. S1 is AgOCs, sensitive up to nearly 12,000 A.U.

V Venetian blind, CsSb coated dynodes.
V * Venetian blind, AgMgO dynodes.
B Box and Grid CsSb coated dynodes.

SPECTRAL SENSITIVITY
OF
SEMI-TRANSPARENT PHOTOCATHODES



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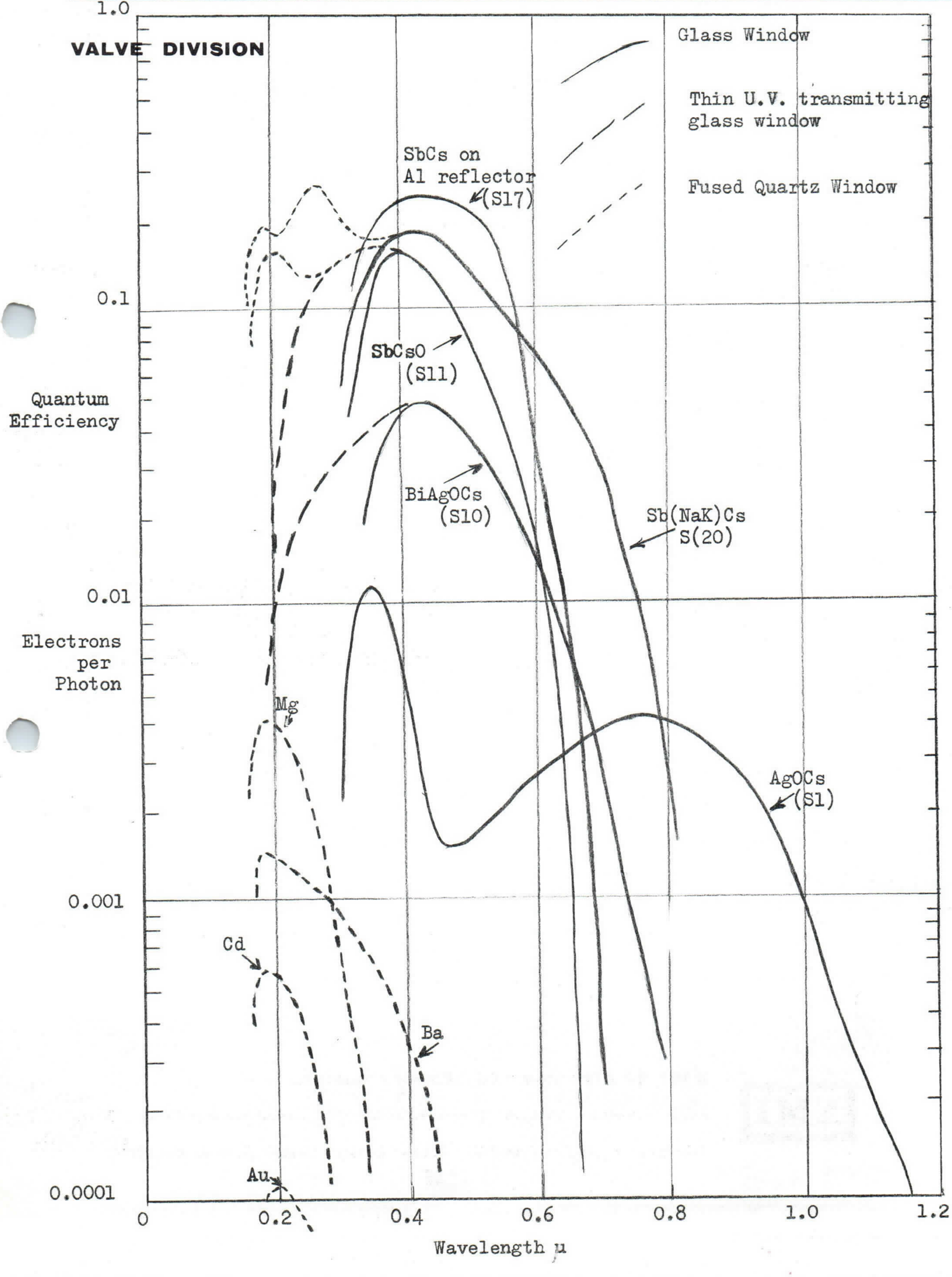
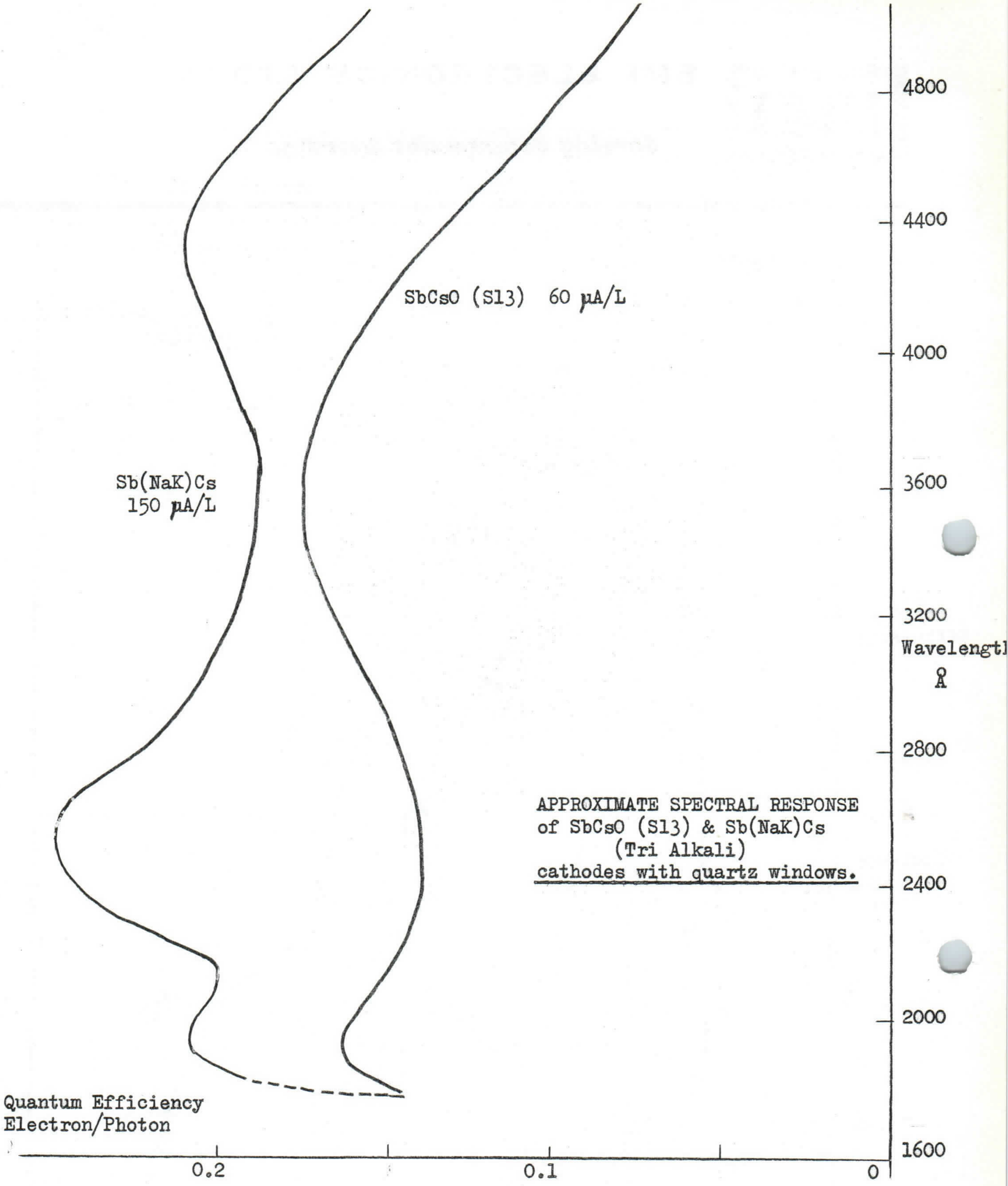
Spectral Response of Various Photocathodes.

VALVE DIVISION





APPROXIMATE SPECTRAL RESPONSE
of SbCsO (S13) & Sb(NaK)Cs
(Tri Alkali)
cathodes with quartz windows.

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EC8/43
18.10.60.

ES8/1086/10M/161/ 38187
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VALVE DIVISION

Photomultipliers for Scintillation Counting

This data-sheet briefly describes a range of photomultipliers manufactured to the highest standards of accuracy and reliability.

E. M. I. (ELEC

VALVE

Photomultipliers for

page 8 9 4 7 4

Tube Type	9524B	9526B	9524S	6097B	6097E	6097G	6097F	6097	9
Description	11 Box SbCs		11 Box SbCs	11 Venetian Blind SbCs	: : :	: : :	: : :	: : :	11 V Blin SbNa
Base	14 Pin Glass		14 Pin Glass	15 Pin Glass	:	:	:	:	20 P
Seated length	112 mm		112 mm	112 mm	:	:	:	:	140
Max. dia.	28.6 mm (1⅛")	30.5 mm	28.6 mm	51 mm	:	:	:	:	51 m
Window dia.	28.6 mm	As 9524B but with fused quartz face plate	28.6 mm	51 mm	:	:	:	:	51 m
Cathode dia.	23 mm		23 mm	44 mm	:	:	:	:	44 m
Cathode type	SbCsO		SbCs	SbCsO	:	:	:	SbCs	SbNa
Cathode Connection	Base		Base	Base	:	:	:	:	Base
Cathode Sensitivity (Average) u A/L	50		30	50	55	:	60	30	100
Cathode D1 Voltage	150		150	150	150	:	150	150	150
D1 Gain	6.5		6	5	5.5	:	5.5	4.5	4

Overall Sensitivity or gain (G1)	200 A/L	As 9524B but with fused quartz face plate	200 A/L	200 A/L	200A/L	200A/L	50A/L	200A/L	200
Overall Voltage V	1100		1200	1400	1050	1300	1200	1600	170
Dark Current (at G1) uA	0.01		0.002	0.03	0.02	0.02	0.1	0.002	0.00

Overall Sensitivity or gain (G2)	2000A/L	As 9524B but with fused quartz face plate		2000A/L	2000A/L	2000			
Overall Voltage V	1600			1900	1500	1750			
Dark Current (at G2) uA	0.2			0.3	0.2	0.2			

Max. Output (linear) High Gain m A	5	As 9524B but with fused quartz face plate		10 m A	8 mA	9 mA			
Max. Output (linear) High Current m A	10			50m A	50 mA	50 mA			
Rise Time (High Current condition) musec				7	7	7			
Time Spread " " " musec	20			14	14	14			
Anode connection	Base			Base	Base	Base	Base	Base	Bas
Notes				Also available with overcapped diheptal base as 9584B					

7.4.59

RONICS) LTD.

DIVISION

Scintillation Counting

2	5	~~4,5~~ 18	4,5	7,19	7,10	7	11		4	12	13	
58B	9514B	6255B	9514S	9531B	9530B	9545B	9536B	9552B	9536S	9578B	9579B	9578TA
enetian	13 Venetian		:	11 Venetian	:	:	10 Venetian	:	:	:	:	10 Venetian
d	Blind		:	Blind	:	:	Blind	:	:	:	:	Blind
KCa	SbCs		:	SbCs	:	:	SbCs	:	:	:	:	SbNaKCs
in Glass	15 Pin Glass		:	15 Pin Glass	:	:	Diheptal	:	:	:	:	Diheptal
m	121 mm		:	155 mm	170 mm	360 mm	$4\frac{7}{8}$"	:	:	$5\frac{3}{8}$"	$6\frac{3}{4}$"	$5\frac{3}{8}$"
n	51 mm	51.5 mm	51 mm	91 mm	127 mm	310 mm	$2\frac{1}{4}$"	:	:	$3\frac{3}{32}$"	5"	$3\frac{3}{32}$"
n	51 mm	As 9514B but with fused quartz face plate	:	91 mm	127 mm	310 mm	$2\frac{1}{16}$"	As 9536B but with fused quartz face plate	:	$3\frac{3}{32}$"	5"	$3\frac{3}{32}$"
n	44mm		:	15 mm	111 mm	250	$1\frac{3}{4}$"		:	$2\frac{1}{2}$"	$4\frac{3}{8}$"	$2\frac{1}{2}$"
KCa	SbCsO		SbCs	SbCsO	SbCsO	SbCsO	SbCsO		SbCs	SbCsO	SbCsO	SbNaKCs
	Base		Base	Base	Base	Side	Base		Base	Base	Base	Base
	50		30	50	50	40	50		30	50	50	100
	150		150	300	450	600	150		150	300	450	300
	5		4.5	6	6	6	5		4	6	6	4

/L	2000A/L	As 9514B but with fused quartz face plate	2000A/L	200A/L	200A/L	200	50A/L	As 9536B but with fused quartz face plate	50A/L	50A/L	50A/L	
	1400		1700V	1400V	1500V	2000	1400		1600	1450	1450	
3	0.2		0.02	0.15	0.25	1.0	0.008		0.001	0.02	0.04	

	10000A/L	As 9514B but with fused quartz face plate					200A/L	As 9536B but with fused quartz face plate	200A/L	200A/L	200A/L	200A/L
	1800						1700		1900	1750V	1800V	1900
	2						.03		.003	0.1	0.2	0.01

	8 mA	As 9514B but with fused quartz face plate					10 mA	As 9536B but with fused quartz face plate		10 mA	10 mA	
	50 mA						50 mA			50 mA	50 mA	
	8						6					
	16						14					
e	Base		Base	Base	Base	Base	Base					
					Also available with diheptal base as 9583B							

VALVE DIVISION'S PRODUCTS INCLUDE :-

CATHODE RAY TUBES MAGNETRONS KLYSTRONS
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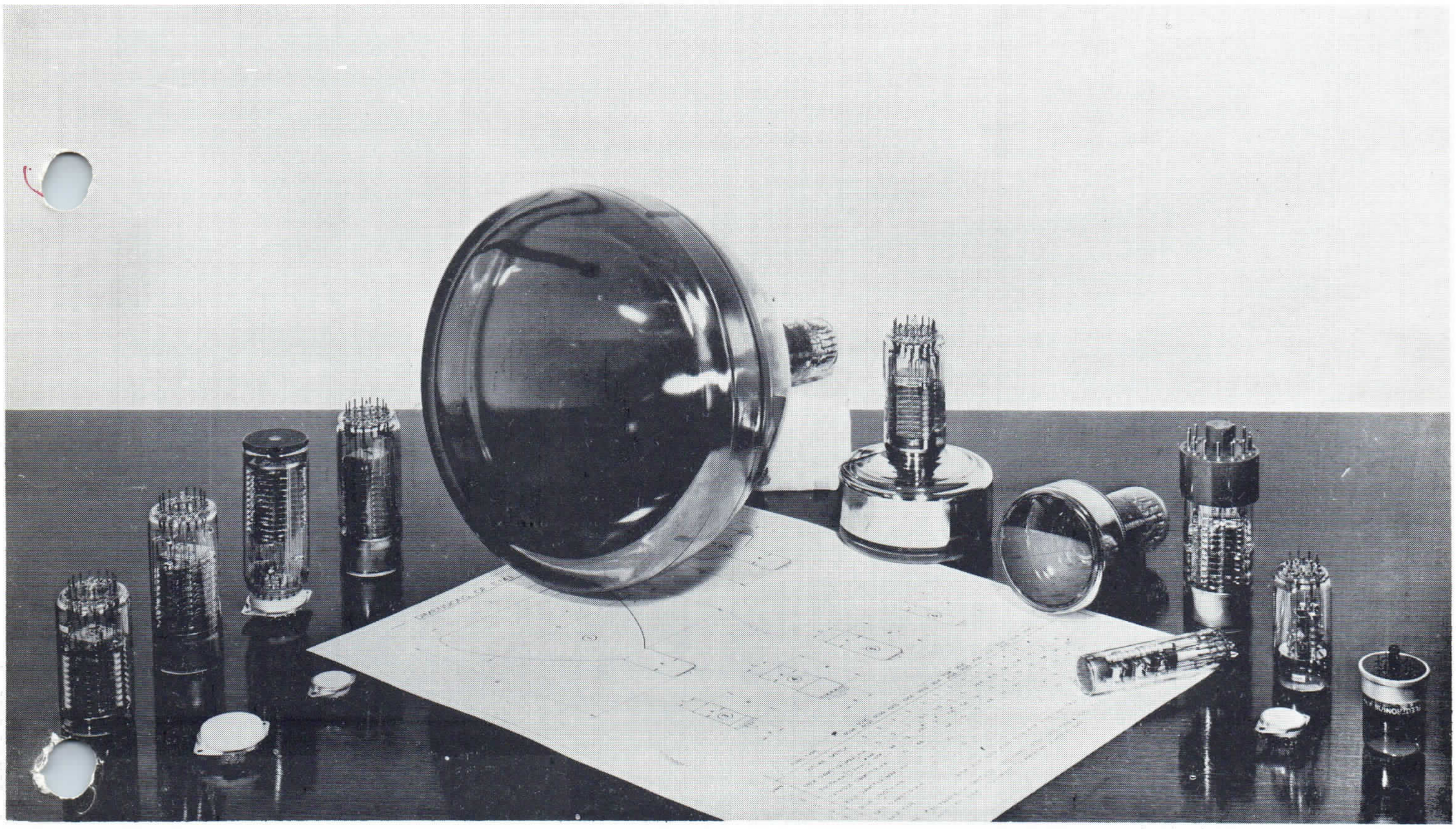
E·M·I

PHOTOMULTIPLIERS

11-STAGE PHOTOMULTIPLIER TUBES WITH VENETIAN BLIND DYNODES



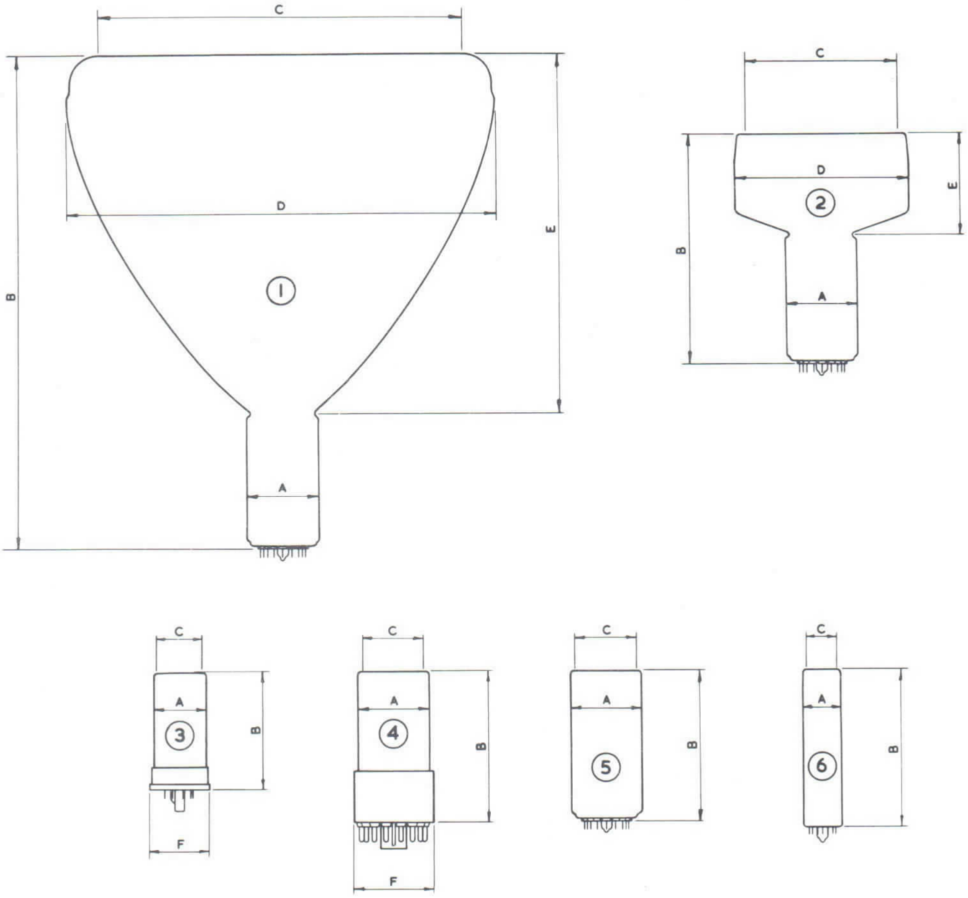
TYPE NUMBERS

9545B	9530B	9531B
6097B	6094B	6095B

II STAGE PHOTOMULTIPLIER TUBES

These tubes utilise the E.M.I. Venetian Blind structure in which the secondary emission surfaces are coated with Antimony-Caesium. They feature semi-transparent end-window photocathodes and high efficiency electron collection by the first dynode. The tube design is such that the gain-dark current characteristics are particularly good and higher than average potentials may be applied to the last few dynodes, so increasing the linear range of peak output current up to values of 50—100 mA.

— DIMENSIONS OF E.M.I. PHOTOMULTIPLIER TUBES. —



	TUBE TYPE:	6094	6095 6097	6099	6255	6256	9502	9514	9524 9528	9526 9529	9530	9531	9533 9535	9536	9545	
DIMN.	OUTLINE SKETCH:	5	5	2	5	5	5	5	6	6	2	2	3	4	1	
A	NECK DIAMETER [MAX] m.m.	51	51	51	51·5	51·5	51	51	28·6	30·5	54	54	40	51	56	
B	LENGTH.m.m. [±3m.m.] * see note.	94	112	230*	121*	108*	108	121	112	112	170	155	84	128	360*	
C	CATHODE DIAMETER m.m.	10	44	111	44	10	10	44	23	23	111	75	38	44	250	
D	BULB DIAMETER [MAX] m.m.	–	–	130	–	–	–	–	–	–	127	91	–	–	310	
E	BULB LENGTH. m.m.	–	–	135	–	–	–	–	–	–	70	55	–	–	257	
F	BASE DIAMETER. m.m.	–	–	–	–	–	–	–	–	–	–	–	44	57	–	
	BASE TYPE.	B.15.B.	B.15.B.	B.15.B.	B.15.B.	B.15.B.	B.15.B.	B.15.B.	14 pin.	14 pin.	B.15.B.	B.15.B.	B.9.G.	B.14.A.	B.15.B.	

NOTE: *TOLERANCE ON LENGTH OF TUBES TYPES 6099, 6255, 6256 & 9545: ±6 m.m.
BASE TYPE B.14.A. IS EQUIVALENT TO AMERICAN DI-HEPTAL BASE.

The curves Fig. I and II give the characteristics of the 6097B with two recommended types of dynode chain. In particular Fig. I shows typical characteristics obtained with 400V applied between the last few dynodes allowing peak output currents of 50mA to be drawn with good linearity. The saturation currents are then well above 150 mA. Characteristics of the other tubes in the table will be similar so far as gain is concerned provided that the supply voltage is adjusted to allow for the specified values of Cathode-D1 voltage. Dark currents are given in the table and may be converted to equivalent input lumens if divided by the appropriate overall sensitivity figure.

$$\text{Equivalent input lumens} = \frac{\text{dark current } (\mu A)}{\text{overall sensitivity } \times 10^6}$$

Time Resolution: At a gain of 2000 A/L the 6097B will have a resolution time (full width at half maximum amplitude) of 14 mμ sec. when used with dynode potentials specified in Fig. I.

The tubes which have S11 cathode may also be provided with the E.M.I. type S cathode (e.g. 6097S) which has a reduced red sensitivity, and hence a reduced thermionic emission from the photocathode, and is especially suitable for the scintillation counting of low energy particles (e.g. C^{14} and H^3 beta particles). Tubes with suffix "F" (6097F) have S11 cathodes of minimum photosensitivity of 40μ A/L, and are specially recommended for gamma ray spectrometry. The dark current-gain specification will be slightly inferior to the B type.

These tubes may also be provided to special order with either the S10 cathode, or the S1 cathode which has sensitivity up to 12000 AU.

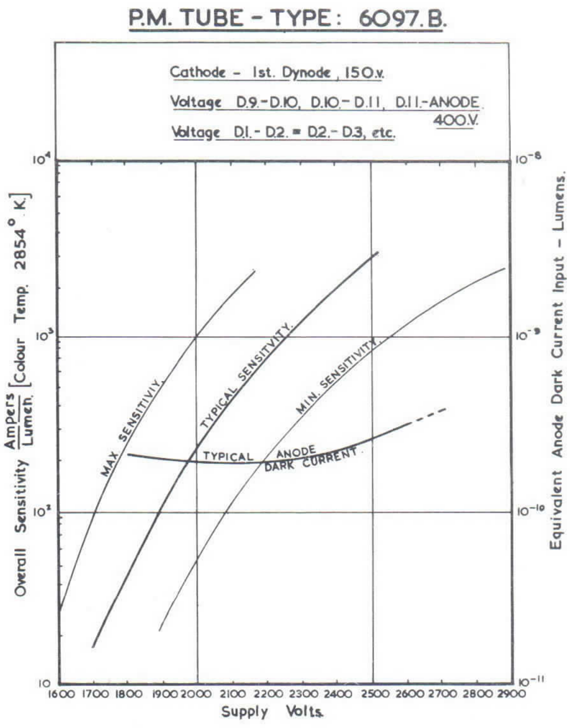


FIG. I

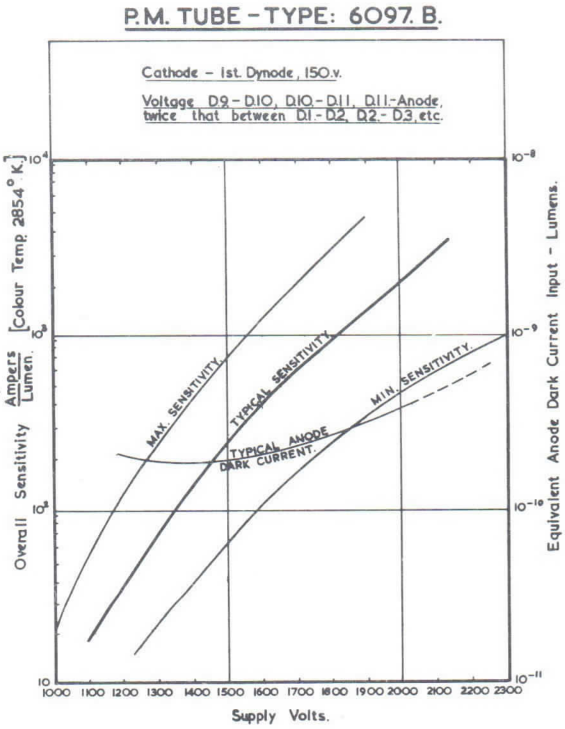


FIG. II

TECHNICAL SPECIFICATION

Tube Type	No. of Stages	Cathode Diameter	Photocathode Spectral Response	Window Glass	Minimum Photosensitivity	Minimum Overall Sensitivity at 160V Stage or less	Max. Dark Current at Min. Overall Sensitivity	Cathode—DI	Average Photosensitivity	AVERAGE CHARACTERISTICS AT OVERALL SENSITIVITY OF						TYPICAL APPLICATIONS AND NOTES
										20 A/L		200 A/L		2000 A/L		
										Supply Volts	Dark Current	Supply Volts	Dark Current	Supply Volts	Dark Current	
		mm			µA/L	A/L	µA	V	µA/L	V	µA	V	µA	V	µA	
9545B	11	250	S11	Sodaglass	30	200	4.0	600	50			2200	1.0			Large area photocathode; suitable for scintillation counters for geological surveys. A focussing electrode is provided which may be adjusted to give optimum results.
9530B	11	111	S11	Pyrex	30	200	1.0	450	50	1550	0.03	2000	0.3	2650	3.0	For general scintillation counting and flying spot scanning. A focussing electrode is provided which may be adjusted to give optimum results.
9531B	11	75	S11	Pyrex	30	200	0.5	300	50	1400	0.02	1850	0.2	2500	2.0	Especially recommended for gamma ray spectrometry. A focussing electrode is provided which may be adjusted to give optimum results.
6097B	11	44	S11	Pyrex or Soda	30	200	0.1	150	50	1150 1200 1700	0.008 0.005 0.005	1525 1600 2000	0.05 0.04 0.04	2000 2400	0.5 0.5	A general purpose tube for scintillation counting, flying spot scanning, spectrophotometry, etc.
6094B	11	10	S11	Kodial	30	200	0.01	150	50	1150	0.002	1525	0.005			A small diameter photocathode tube suitable f[illegible]ectro-photometry and certain scintillation counti[illegible]
6095B	11	44	S10	Pyrex	20	200	0.1	150	30	1250	0.01	1700	0.07			For colour television flying spot scanning, photometry and other applications.

A/L:— Ampere/Lumen
S10 spectral response is obtained by use of Bismuth-Silver-Caesium photocathode (See Fig. III).
S11 ,, ,, ,, ,, ,, ,, Caesium-Antimony photocathode (See Fig. III).

SPECTRAL RESPONSE OF TYPICAL PHOTOCATHODES.

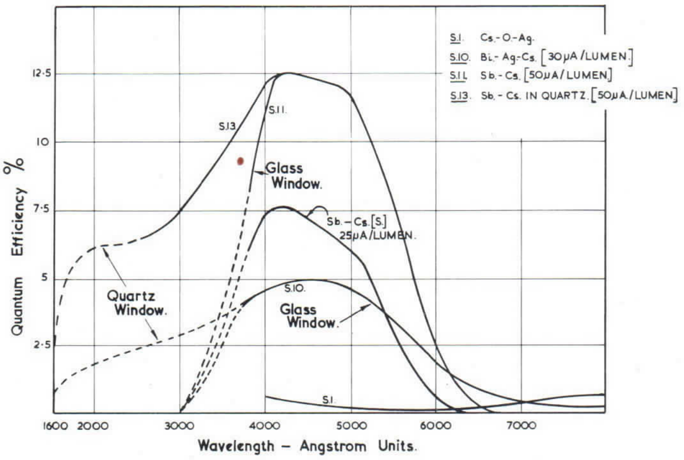


FIG. III

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Top	Side	Tube Type	Base
Dynode	5	7	9	11	—	A	—	10	8	6	4	2	K	1	3	—	—	6097 6094 6095	B15B
,,	—	1	3	5	7	9	11	A	10	8	6	4	2	F	K	—	—	9530 9531	B15B
,,	IC	1	3	5	7	9	11	A	10	8	6	4	2	F	—	—	K	9545	B15B

K—Cathode. *A—Final anode or collector.* *F—Focussing electrode (connect to D1 for most applications).* *IC—Internal Connection.*

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P.S. 948 T.P.

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EMI PHOTOMULTIPLIER TUBES

EMI are the largest producers in Europe of Photomultiplier Tubes which are designed to convert very low levels of illumination into usable values of electric current, and are extensively used in radio astronomy, spectro-photo-metry, scintillation counters, gamma-ray spectroscopy and similar applications. Special features of EMI Photomultipliers are that every one is tested three times for consistency of performance and reliability and the complete guarantee of performance which they carry.

All EMI tubes are made with a pressed glass base, for which sockets moulded in teflon are available. By this means, trouble with hygroscopic materials such as bakelite, is avoided but concomitantly, the simple method of making an assembly light tight by taping over an opaque base, such as is possible with an overcapped tube, cannot be used. Partly with this in mind, 11 and 10-stage tubes, overcapped with di-heptel bases are available in the range. The great advantage of the glass base, however, shows up in the small diameter tubes, which, socket and all, will pass through a 1⅛ inch cylinder.

The envelope for most tubes is either Pyrex or Lime Soda, going through a graded seal to a Kovar-sealing glass base in the former case. The intention here is of course to remove any potassium content as far from the window as possible.

A tube type which has long been available in our range has a fused silica end window, giving UV sensitivity down to 1600 AU, and is now made in both 2-inch and 1⅛ inch sizes.

All the tubes in the standard EMI range are now free of Embargo.

TUBE TYPE NUMBERS

6094B
6095B
6097B
6097F
6097S
6255B
6256B
6256S
9502B
9502S
9514B
9514S
9524B
9524S
9526B
9528B
9529B
9530B
9531B
9536B
9536S
9545B
9552B
*9554B
9578B
9578TA
*9578IR
9579B
9583B
9584B
9558B

The suffix letter associated with the general type number indicates the specification to which the tube is tested before despatch. 'A' class tubes selected for a particular parameter are available in small quantities at an extra charge of £5. per tube. 'S' tubes type 6097, 9536, 9514 and 9524 having cathodes of low thermionic emission and suitable for the scintillation counting of low energy particles are subjected to an H3 counting test at an extra charge of £4 per tube.

Tubes can be supplied with a NESA coating to increase cathode conductivity and to enable operation at -180° C, at prices 50% above those shown. Magnetic shields are available for the range of tubes.

PACKING SPECIFICATION

Photomultiplier Tubes

Types	Basic Air Freight approx. dimensions	Approx. Gross Weight
6094, 6095, 6097 6255, 6256, 9502 9514, 9536, 9584 9554	Single Pack 9 in x 6 in x 6 in	1-lb 8-oz
	Double Pack 9½ in x 6 in x 8½ in	2-lb 8-oz
9530, 9552, 9578 9579, 9582	11¾ in x 10½ in x 10½ in	4-lb 12-oz
9531	11¾ in x 10½ in x 10½ in	4-lb 4-oz
6099, 9583	18 in x 13 in x 12¼ in	6-lb 8-oz
9524, 9526, 9528 9529	7¼ in x 3½ in x 3½ in	1-lb 4-oz
9545	24 in x 16 in x 13 in	16-lb
9558	10 in x 7¼ in x 7¼ in	2-lb 4-oz

TD

EC8/76
21.7.6

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PHOTOMULTIPLIER TUBE APPLICATIONS

6095	Eye corrected photometer flame spectrophotometers red channel of flying spot colour television.
6097	General purpose blue/green sensitive Photomultiplier tube for scintillation counting, Flying Spot Film scanner application, etc.
6097F	Gamma ray spectroscopy, Flying Spot film scanner application.
6097S	Version of the 6097 with very low thermionic emission C^{14} and H^{3} counting.
6255B	Quartz window tube for vacuum and general spectrophotometry and for scintillation counting with gas and liquid phosphors.
6256B	1 cm. cathode quartz window tube for spectrophotometry.
6256S	Low dark current version of 6256B.
9502B	Glass window version of 6256B for spectrophotometry in visible region.
9502S	Low dark current version of 9502B.
9514B	General purpose high gain Photomultiplier.
9514S	Low dark current version of 9514B for scintillation counting of H^{3} and C^{14}.
9524B	General purpose small diameter tube, particularly suitable for bore hole logging, portable scintillation counters and complete telecine.
9524S	Low dark current version of 9524B, suitable for X Ray scintillation spectrometry and counting of C^{14} and H^{3}.
9526B	Quartz window version of 9524, for U.V. Spectrometers, etc.
9528B	Red sensitive version of 9524B for photometers, flame spectrometers, telecine red channel, etc.
9529B	Quartz window version of 9528B, suitable for wide range spectrophotometers.
9530B	5 in. dia. general purpose tube for scintillation counting with large area crystals for alpha counting, and similar applications.
9531B	3½ in. general purpose tube which is particularly suitable for high energy resolution gamma ray spectrometry. This tube also finds application in some photographic printing apparatus.
9531IR	Version of 9531 with infra-red sensitive cathode extending to just over 1μ. This tube is made to special order.

continued:

9536B	General purpose overcapped 10 stage tube which will operate in place of the Du Mont 6292. This tube is suitable for scintillation counting.
9536S	Low dark current version of 9536B, suitable for scintillation counting of Tritium and C^{14}. This tube is used in American equipments.
9545B	12 in. general purpose tube suitable for large area scintillation counting and for photographic printing applications. This tube could also be used in a Flying Spot live transmission television system.
9552B	Quartz window version of 9536B for spectrophotometers and for scintillation counting using gas and liquid phosphors.
9553B	Infra-red cathode version of 9536B, made only to special order and has long delivery.
9554B	Red sensitivity version of 9536B suitable for visual spectrometry and for red channel in telecine apparatus.
9558	Special 11 stage tube with tri-alkali cathode and very low dark current, suitable for flame spectrophotometers, for astronomical applications, and for colour channel of Flying Spot telecine.
9567B	Infra-red cathode version of 9530B. This tube has found application in the manufacture of photographic emulsions.
9578B	3 in. overcapped 10 stage tube which will operate in place of the Du Mont 6363 for general purpose scintillation counting and gamma ray spectrometry.
9578TA	Tri-Alkali cathode version of 9578B very suitable for red channel of Flying Spot telecine.
9579B	10 stage overcapped 5 in. dia. tube which will operate in place of the Du Mont 6364. This is a general purpose tube suitable for scintillation counting.
9582B	Infra-red cathode version of 9579B made only to special order.
9583B	Overcapped version of 9530B.
9584B	Overcapped version of 6097B. This tube will operate in place of the Dario 53AVP.
9592B	As 9529 with Corning UV glass, S10 Cathode.
9593B	High gain, high output current, $m\mu$ sec. resolution.
9600	Similar to 9524 but with Photo cathode extended down side walls for use in large area monitor probes.
9603	Particle multiplier.
9607	Similar in construction to 9558 but with multi-alkali photo cathode for high temperature and AgMgO coated dynodes.

EC8/29
5.7.60.

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Mumetal Shields for Photomultipliers

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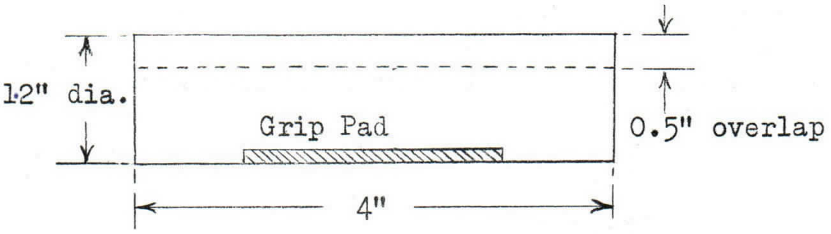
Mumetal Shields for E.M.I. Photomultipliers

Type 8A

Suitable for $1\frac{1}{8}$" dia. Photomultiplier tubes.

Length : 4 inches

Fixing : Self Sprung.

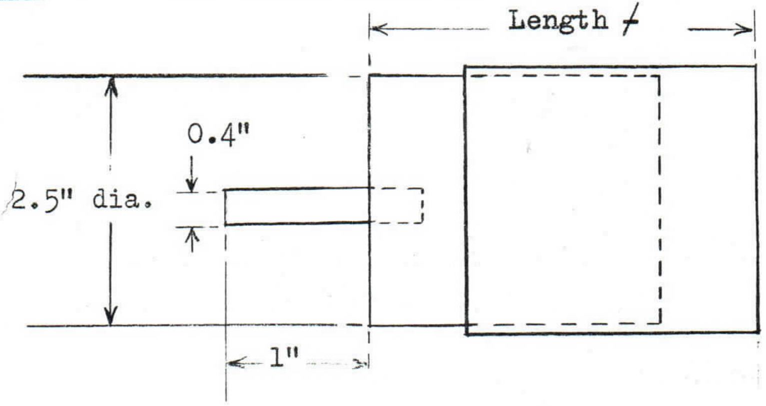


Type 6B

Suitable for 2" dia. Photomultiplier tubes.

Length : Adjustable - 2.75", 3.50", 4.25" and 5.00"

Fixing : B15B Socket mounting



Type 12C

Suitable for diameters of 3" to 5".

A $17\frac{1}{2}$" length of mumetal $5\frac{1}{2}$" wide, rolled to form a cylinder, the diameter of which is adjustable by two external clips.

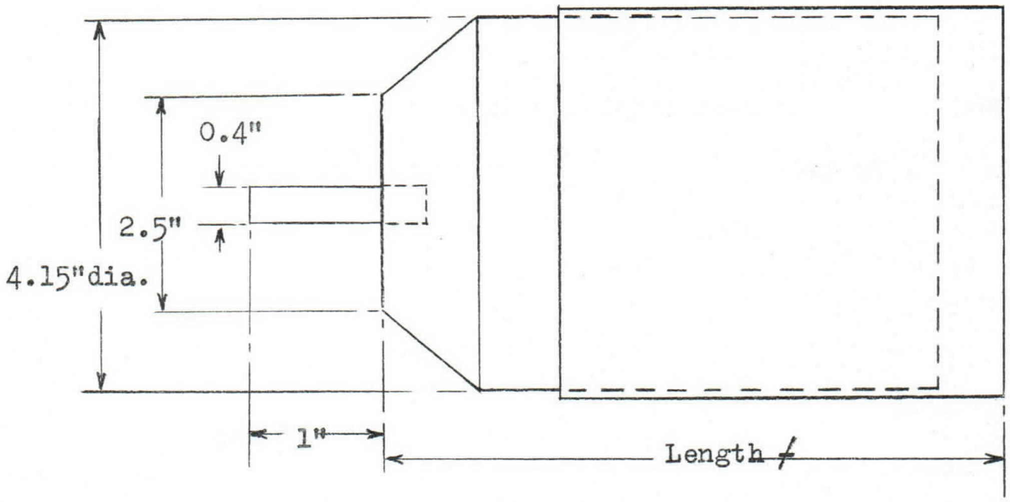
Mumetal shields for E.M.I. Photomultipliers.

Type 7B

Suitable for 3" dia. Photomultiplier tubes.

⨍ **Length** : Adjustable - 5", 5.95", 6.90", 7.85" and 8.80"

Fixing : B15B Socket Mounting

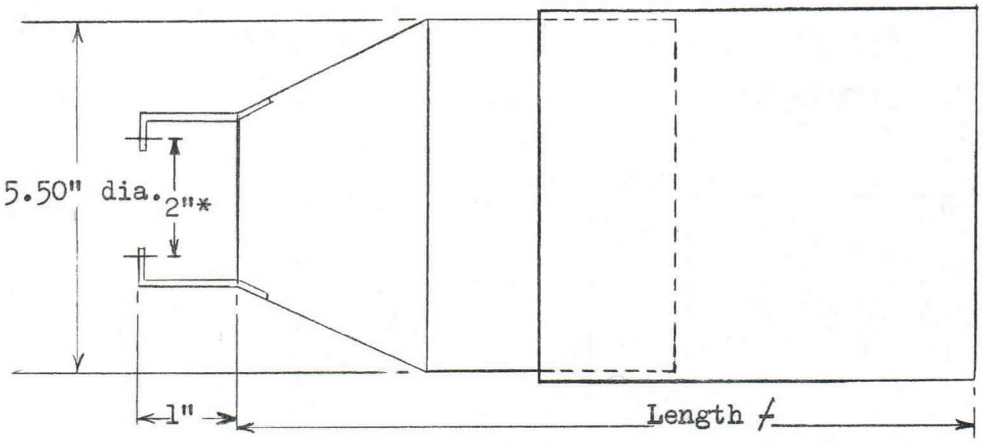


Type 9B

Suitable for 5" dia. Photomultiplier tubes.

Length : Adjustable (5.60", 6.55", 7.50", 8.45", 9.40" and 10.35")

Fixing : B15B Socket Mounting.



* 2" centres
as 6B and 7B
screens for
B15B socket.

EC8/56 -R
7.2.61.

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P1060

assembly

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Three inch Matched Crystal & Photomultiplier Assembly (P 1060)

A thallium-activated sodium iodide crystal, when mounted direct on a photomultiplier, gives a better resolution than when it is mounted in a windowed can and placed in contact with the photomultiplier.

A specially selected Hilger and Watts crystal, 3 inches in diameter and 3 inches thick, is mounted direct on the face of an E.M.I. type 9531A photomultiplier, but before sealing the two together, the optimum orientation of the crystal relative to the photomultiplier is carefully determined.

The unit is hermetically sealed and supported on a spring-loaded shock mounting within a strong outer case. This also protects the photomultiplier from damage by being flooded with light.

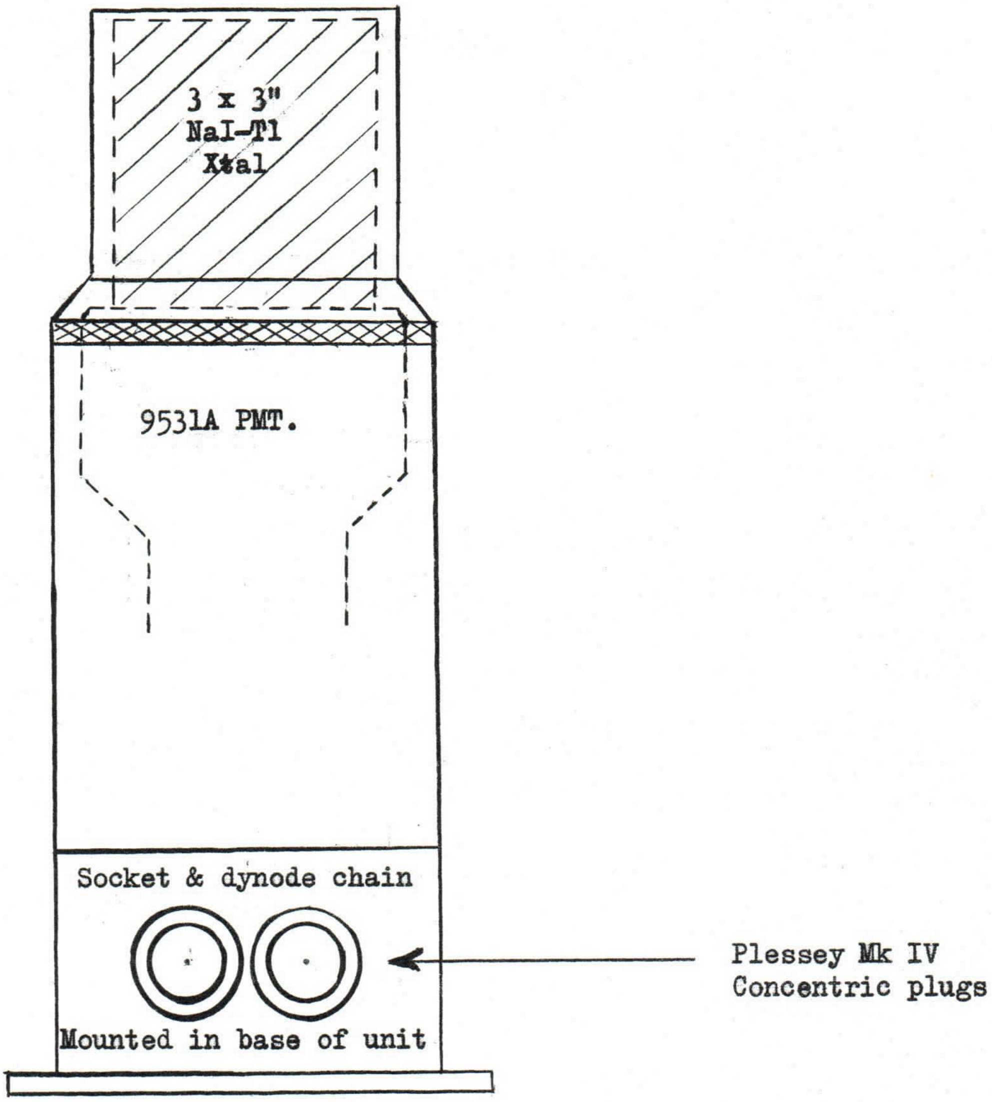
The whole assembly is intended for bench mounting.

Light transfer from the crystal to the photomultiplier is as high as possible because the two are in contact.

The optimum e.h.t. voltage, determined experimentally, is specified for each assembly.

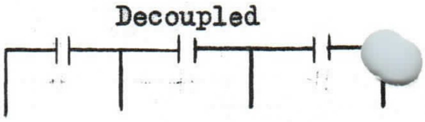
Resolution is typified by a C_s^{137} resolution of 8% and a peak-to-valley ratio of 4:1 with a Co-60 source, and will satisfy the needs of gamma-ray spectrometers requiring the best possible resolution.

Background radiation is due almost entirely to a small potassium impurity and will not normally exceed 8 counts per second, at a low bias level.



1.4 Meg.

Dynode Resistor Chain.



2.4 Meg 1.1 Meg 1 Meg 1 Meg . . . . 2.2 M 2.2 M 2.2 M

C - Focus - D1 - D2 - D3 - D4 - D5 - D6 - - - D9 - D10 - D11 - Anode

Anode load 10 K Ω

Coupling capacitor 68 pf

EC8/39
4.10.60.

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SCINTILLATION COUNTERS

Energy resolution of Phosphor-Photomultiplier combinations

In a gamma ray spectrometer consisting of a crystal of sodium iodide (thallium activated), coupled to an end-window Photomultiplier tube, the energy resolution is dependent on the energy of the gamma ray, the quality of the crystal, the photosensitivity of the photocathode and its uniformity, the efficiency of collection of photoelectrons into the first dynode and the gain of the first dynode. The fractional standard deviation of the statistical spread in the electron signal leaving D3 may be written as follows :-

$$\sigma_1 = (E.\eta\, r\, F)^{-\frac{1}{2}} \left(1+ \frac{1}{g_1 \delta_1} + \frac{1}{g_1 \delta_1 (g\delta-1)}\right)^{\frac{1}{2}}$$

where E is the gamma ray energy. η & r is the product of photosensitivity and scintillation conversion efficiency of Kinetic energy into light ($= \frac{1}{W}$ where w = eV per photoelectron) ; R is a factor describing phosphor and cathode uniformity and light collection efficiency; F is the efficiency of collection of photoelectrons into D1; $g_1 D_1$ is D1 gain and $g\delta$ is the average dynode gain after D1. (δ is the coefficient of secondary emission for the particular dynode surface).

Typically, for NaI-Tl and E.M.I. tubes, W = 250 eV/electron and for an E.M.I. 9531B : $F \approx 0.9$ and $g_1 \delta_1 = 6$ and $g\delta = 4$, giving :

$$\sigma_1 = \left(\frac{E}{250}\ 0.9\right)^{-\frac{1}{2}} x\ 1.1 = E^{-\frac{1}{2}} x\ 18.3 = 18.3.E^{-\frac{1}{2}}$$

For E = 661,000 eV (Cs^{137} gamma ray). $\sigma_1 = 0.0215$

If the amplitude distribution of pulses from the Photomultiplier were only determined by the statistics of photoelectron emission, the example given above would give a full width at half maximum (see Figure overleaf) of $2.36\,\sigma_1 = 0.051$ for Cs^{137}. In fact, it is found that a resolution of 0.078 (or 7.8%) is measured and this is due to a 'spreading' mechanism within the crystal (possibly associated with the distribution of electron energy among delta rays), which gives a contribution of 0.06 or 6%. The combination of the two statistical spreads, $\left((0.051)^2 + (0.06)^2\right)^{\frac{1}{2}} = 0.078$.

For other energies and for Photomultiplier tubes of cathode sensitivity different from that giving W = 250 eV/photoelectron, it is found that the resolution can be expressed by an equation

$$\text{Resolution, \%,} = \left(\frac{100{,}000}{E.P} + \frac{3.3}{E^{\frac{1}{2}}}\right)^{\frac{1}{2}}.100$$

Here P is the photosensitivity of an S-11 cathode in µA/Lumen.

/continued .....

Scintillation Counters - continued

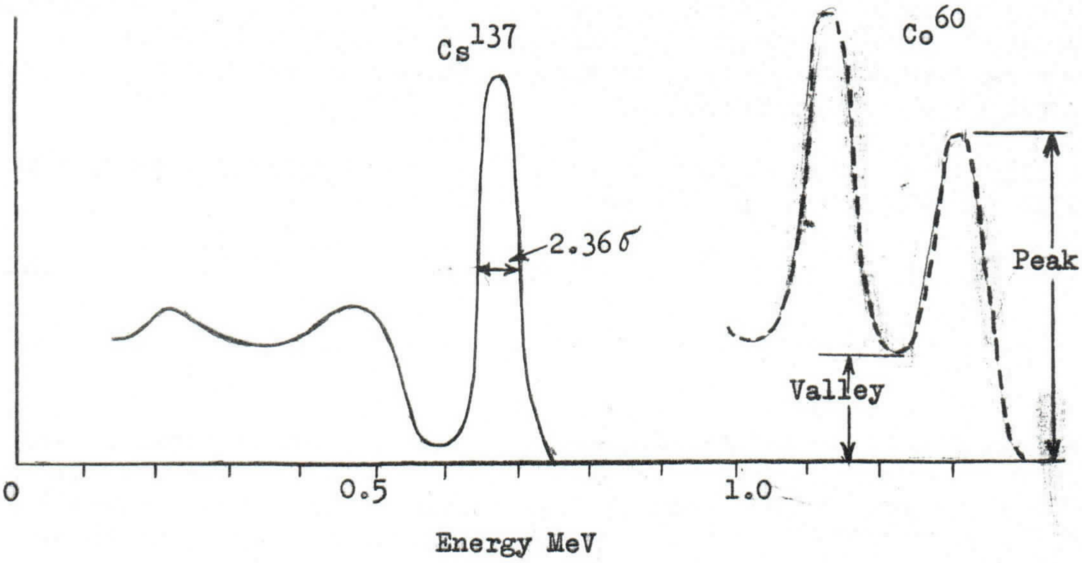
From the Table below it will be seen that at 1MeV the effect of photosensitivity is relatively small, but at low energies the resolution is determined mainly by the photoelectron statistics.

The assessment of energy resolution of a γ ray spectrometer is often made using the photopeak of Cs^{137}. Owing to the difficulty of measuring the width at half maximum really accurately, it is often useful in practice to use the peak-valley ratio for Co^{60} (see figure below) as a more sensitive indicator. A value of 4:1 may be considered equivalent to a Cs^{137} resolution of better then 8%.

Table of Resolution for various energies and values of photosensitivity.

P µA/L	90 µ A/L		60 µ A/L			30 µ A/L	
EeV	10^6 eV	10^4 eV	10^6	661,000	10^4	10^6	10^4
Resolution %	6.65	38	7.05	8.1	45	8.15	60

Resolution of γ ray Spectrometers.



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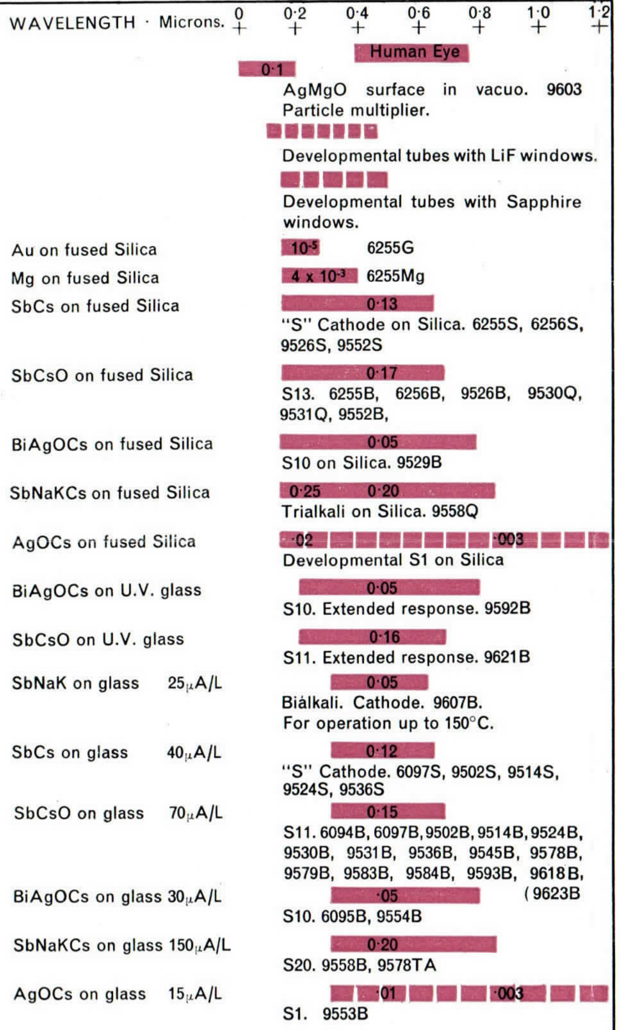
P tomultiplier tube selection cha

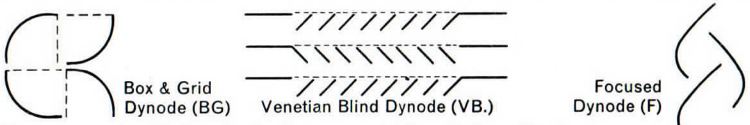
PHOTOCATHODE DATA

The range of spectral sensitivity is given with quantum efficiency (Electrons per photon) at points indicated. Tubes having given end-window cathode type are listed.



		0·1	AgMgO surface in vacuo. 9603 Particle multiplier.
			Developmental tubes with LiF windows.
			Developmental tubes with Sapphire windows.
Au on fused Silica		10⁻⁵	6255G
Mg on fused Silica		4 x 10⁻³	6255Mg
SbCs on fused Silica		0·13	"S" Cathode on Silica. 6255S, 6256S, 9526S, 9552S
SbCsO on fused Silica		0·17	S13. 6255B, 6256B, 9526B, 9530Q, 9531Q, 9552B,
BiAgOCs on fused Silica		0·05	S10 on Silica. 9529B
SbNaKCs on fused Silica		0·25 0·20	Trialkali on Silica. 9558Q
AgOCs on fused Silica		·02 ·003	Developmental S1 on Silica
BiAgOCs on U.V. glass		0·05	S10. Extended response. 9592B
SbCsO on U.V. glass		0·16	S11. Extended response. 9621B
SbNaK on glass	25μA/L	0·05	Biálkali. Cathode. 9607B. For operation up to 150°C.
SbCs on glass	40μA/L	0·12	"S" Cathode. 6097S, 9502S, 9514S, 9524S, 9536S
SbCsO on glass	70μA/L	0·15	S11. 6094B, 6097B, 9502B, 9514B, 9524B, 9530B, 9531B, 9536B, 9545B, 9578B, 9579B, 9583B, 9584B, 9593B, 9618B, (9623B
BiAgOCs on glass	30μA/L	·05	S10. 6095B, 9554B
SbNaKCs on glass	150μA/L	0·20	S20. 9558B, 9578TA
AgOCs on glass	15μA/L	·01 ·003	S1. 9553B

DYNODE CHARACTERISTICS



Tubes are made with dynode structures appropriate to their application.

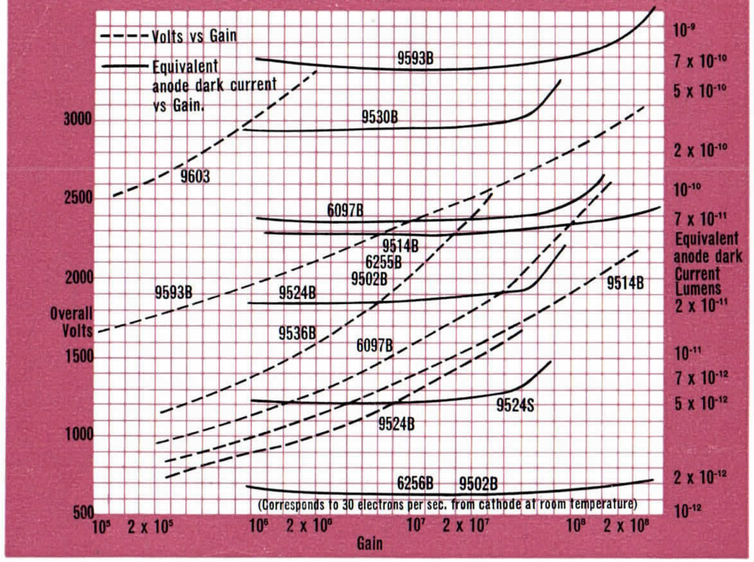
Box & Grid (Coated with SbCs). Give very high stage gain at low voltage and are used in small diameter tubes (e.g. 9524B) particularly for portable apparatus. Time characteristics are relatively poor, and peak anode currents are limited to about 50mA.*

Venetian Blind dynodes (SbCs Coated). Give good average gain and very low dark currents. The large diameter allows of good collection efficiency from the cathode. Rise times of 2″ tubes are about 7 nanoseconds and peak currents up to 300 mA may be drawn.

Focused structures (AgMgOCs) give very good time characteristics, with rise times around 2½ nanosecs, but gain is relatively lower than the other ~~types and~~ dark current worse.

AgMgO dynodes (whether F or VB) made without Cs in the tube (e.g. 6255G, 9607) give low gains and require high voltage for operation. Dark Current in μA divided by overall sensitivity in Amps per Lumen gives equivalent Dark Current in Lumens and should be independent of gain. (*Note. Average anode currents are limited to 1mA max.)

GAIN & DARK CURRENT CHARACTERISTICS



Note: The dark current of a PM tube may be relatively high when the tube is first operated, but will quickly decrease during operation in the dark, and may go on decreasing for several days before reaching a limiting value.

For further details, please write or telephone: **E.M.I. ELECTRONICS LTD**

ENVELOPE DIAMETER

½″ 13mm	1″ 25mm	2″ 50mm	3″	5″ 130mm	7″	10″	12″ 300mm
	11BG 9524 9526 9529 9592 9600* 9621 (B14B)	10VB 9536 9552 9553 9554 (B14A) 11VB 9584 (B14A)	10VB 9578 (B14A) 11VB 9531 (B15B)	10VB 9579 (B14A) 11VB 9583 (B14A) 9530 9618 (B15B)	11VB 9623 (B15B)		11VB 9545 (B15B)
Developmental		6094** 6095 6097 (B15B) 9558 9607† (B19A) 13VB 6255 6256** 9502** 9514 (B15B) 14F 9593‡ (B19A)					

NOTES

† AgMgO coated dynodes.

‡ AgMgOCs coated dynodes.

All other tubes have SbCs coated dynodes.

** 10mm cathode.

* Side Wall Sensitive 20cm² total cathode area.

B14A is a Diheptal base, all other bases are of glass.
PTFE Sockets are available for the glass base tubes.
The operation of PM tubes may be affected by magnetic fields and μ-metal shields are available.
PM tubes should not be operated at excessive light levels with voltage applied.
Dark current is dependent on operating temperature. The data given refers to 20°C. A reduction in temperature to −10°C will give a decrease of ca. 10:1.

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E.M.I. PHOTOMULTIPLIER TUBES

The development of photoelectric cells in the 1920's resulted in a vast new field of application, especially in sound recording, but further advances in the use of photoelectricity were prevented by the high noise level of amplifiers capable of dealing with currents of a fraction of a microampere at bandwidths of more than a few kilocycles per second. This situation was completely altered in 1936 by the production of Photomultipliers in which the small photocurrents were amplified by the almost noiseless process of secondary emission, so that the current amplitude was raised to a level at which conventional valves could be used for further signal processing without introducing too much noise.

This early Zworykin multiplier, illustrated in Fig. 1(a), utilises crossed electric and magnetic fields. Photoelectrons from the cathode, accelerated by fields from electrodes 1 and 2, are bent into a cycloidal path by the magnetic field to fall on electrode 2. There, each primary electron gives rise to the emission of a few secondary electrons of comparatively low energy. The electric field from electrode 3 now draws these secondary electrons away from their source and the magnetic field constrains them so that they strike electrode 4, where the production of secondary electrons occurs again. At each dynode, as the secondary emitting electrodes are called, the current is multiplied by a factor proportional to the coefficient of secondary emission, δ (which generally lies between 3 and 7) and the efficiency of transfer, g, from one dynode to the next. The stage gain $g\delta$ is the parameter of practical interest and an average value of 4.5 is readily obtainable. Thus, a tube with 9 dynodes has a gain of $(4.5)^9$, i.e. about 10^6. Since each primary electron from the photocathode is multiplied by approximately the same amount, and since no current flows in the absence of any primary current, the amplification is essentially noiseless.

ELECTROSTATIC MULTIPLIER TUBES

The problem of designing a secondary electron multiplier is one of arranging the electrodes so that the accelerated electrons fall on to a secondary emitting surface with an electric field directed away from it, so that secondaries are extracted and accelerated to the next dynode. This is managed comparatively easily in the original Zworykin device but with the complication of a magnet which must be properly adjusted.

In 1938, Rajchman evolved a purely electrostatic design, sketched in Fig. 1(b) in which the dynode shape was adjusted to give the required field configuration. Dynode structures which form convergent electron optical lenses which tend to focus the electrons into successively smaller areas as the multiplied beam travels down the dynode system, are classified as focussed types.

/contd...

Other, basically unfocussed, types employ grids to accelerate the secondaries away from the dynode surface and two variations are shown in Fig. 2. The venetian blind type, described by Sommer and Turk, in which the grid is attached to the upper surface of a slatted dynode and extracts secondaries from the almost field-free space between the slats of the dynode above, is shown in Fig. 2(a). The box and grid type of unfocussed dynode systems is shown in Fig. 2(b). Here, the grid, attached to the mouth of one dynode, extracts the secondaries from the low field region near the surface of the preceding dynode.

Whatever system is used in a Photomultiplier, the designer is faced with the problem of achieving good collection of electrons from the photocathode on to the first dynode (D_1), and the solution depends on whether a semi-transparent photocathode is used, as in Fig. 2, or the cathode is deposited on an opaque metal electrode. In the latter case, the cathode is mounted at some distance from the glass of the envelope.

In end-window tubes, the electron optical lens between cathode and D_1, which focuses photoelectrons from the cathode into the central region of D_1, is formed between a cylindrical electrode or wall coating, which is at cathode potential and a wire grid connected to D_1 which 'looks' through an aperture in the base of the cylinder. High efficiency of collection of photoelectrons from all points on the photocathode is possible with this arrangement. The good light-collection efficiency of a semi-transparent photocathode mounted on the inner surface of a window makes this design well adapted for use with diffuse light sources.

The operation of all types of multiplier may be affected by stray magnetic fields and it is often desirable to provide a mumetal screen, particularly for those tubes with larger cathode areas.

PHOTOCATHODE AND SECONDARY EMITTING SURFACES

The preceding discussion has dealt with the geometrical problems of Photomultiplier design and we have not yet considered the characteristics of either photocathodes or of the secondary emitting materials used on dynodes.

Perhaps the most widely used photosurface is antimony-caesium, which is a loosely bound composition of formula Cs_3Sb. This has a spectral sensitivity curve as shown in Fig. 3, the detailed shape depending to some extent on the method of preparation. The region of maximum sensitivity is around 4,300 A° and the limit of red sensitivity is about 6,500 to 7,000 A°, while the ultra-violet sensitivity of the surface is dependent on the window

/contd...

material. With normal glass, it does not extend below about 3,300 A°, but a special u.v. transmitting glass is available which extends the range to 2,000 A°, while quartz windows transmit radiation down to 1,600 A°.

A surface with more red response is Bi-Ag-Cs, which has a useful response at 8,500 A° and extends down into the u.v. as far as the window transmission will allow. This surface is not nearly so red sensitive as Cs-O-Ag but has a much higher quantum efficiency, as will be seen in Fig. 3, in which the spectral sensitivity is given as a function of quantum efficiency for surfaces of typical photosensitivity. This latter parameter is expressed in uA/lumen for light from a tungsten lamp operated at a given colour temperature - usually around 2,850°K.

A secondary emitter used in a Photomultiplier must have a useful (greater than 3) value of δ (the secondary emission coefficient) for incident electron energies of less than 200 eV. The primary electrons dissipate their energy close to the surface of the secondary emitting material and communicate some of this to other electrons, which are lifted into the conduction band with enough energy to escape from the surface of the material. At low incident energies, the number of electrons which are potentially able to escape is very small, while at high energies the electron dissipates most of its energy at such a depth in the material that, of the greater number of secondaries produced only a very few manage to reach the surface. The δ curve, plotted against incident energy, thus rises to a maximum value and falls off again, as shown in Fig. 4. The secondary emission coefficient of clean metals tends to be low, having a maximum value around unity, while many oxides, semiconductors and the alkali halides have maximum δ around 10.

The materials mostly used in Photomultipliers are Cs_3Sb (a semiconductor), oxidised silver-magnesium alloy (i.e. effectively MgO) and oxidised Be-Cu alloy (i.e. BeO), the two latter being enhanced by the caesiation of the surface which results from the activation of the photocathode with caesium. Fig 4 shows how the D_1 gain varies with cathode-to-D_1 voltage for two Cs_3Sb dynodes and for a Ag-MgO-Cs dynode.

ELECTRICAL CHARACTERISTICS OF PHOTOMULTIPLIER TUBES

If a photocathode of sensitivity S µA/Lumen is illuminated by light of intensity L lumens, a current of FLS X 10^{-6} amps is collected by the first dynode, F being the collection efficiency. The current reaching the second dynode is then $g_1\delta_1$ FLS where g_1 is the proportion of the δ_1 secondaries from D_1 which read D_2. The output of the tube is then $FLS(g_1\delta_1 g_2\delta_2 \ldots g_n\delta_n) = FLS(g\delta)^n$ if $g_1\delta_1 = g_2\delta_2 = g\delta$. Since δ is approximately proportional to $V^{0.7}$ for Cs_3Sb over the useful range of inter-dynode voltage V, the overall gain of the tube is proportional to $V^{0.7n} = V^{7.7}$ for an eleven-stage tube. Since the gain varies as such a high power of the operating voltage (10 per cent change in V can halve or double $V^{7.7}$), it is necessary to use a very highly stabilised voltage supply to a Photomultiplier tube if reasonable accuracy is required; e.g. for 1 per cent constancy of overall gain the supply must not vary by more than about 0.12 per cent.

/contd..

The output current $FLS(g\delta)^n = i$ will result in a dissipation of iV watts at the collector and it is obvious that in a tube containing caesiated surfaces, this could not be allowed to rise to too high a level as otherwise redistribution of caesium from the collector and the last few dynodes would occur. In practice, most Photomultipliers are limited to a maximum continuous output current of 1 mA, while with some tubes not more than 100 µA should be drawn if maximum stability is required.

The linearity of output current as a function of illumination of the cathode is of great importance in most applications and, excluding the very rare case in which a tube is used at such low gain and therefore at such high illumination that photocathode resistance is significant, any deviation from linearity is mostly due to space charge effects at the collector and the last and penultimate dynodes. (With some tubes containing Ag-MgO dynodes the stage gain varies slightly with the average current passing through the dynode surface.) It is usual to specify a peak current for which the output current does not depart from linearity by more than some factor (say 10 per cent), for a given interstage voltage. So long as the maximum collector wattage or the maximum voltage rating is not exceeded, it is allowable to increase the voltage between D_n and collector and perhaps also between D_n and D_{n-1} so as to increase the linear current available. On the other hand, the voltage specified for linearity to 10 mA, for instance, may be reduced considerably if linearity to only 100 µA is required. (See table 1.) Also, if some compression of the dynamic range of the output signal is required, low collector voltages may ensure that space charge limitation occurs.

The output current from the collector is negative in sign, corresponding to electrons flowing into the output circuit. It is interesting to observe, however, that the current from D_n is opposite in sign, corresponding to electrons flowing from the dynode. This is useful when observing fast pulses in scintillation counters.

Since the photocathodes used in Photomultiplier tubes have useful sensitivity in the visible region, they will emit thermionic electrons, even at room temperature and the longer the wavelength to which they are sensitive, the greater will be the thermionic emission. An average semi-transparent Cs_3Sb cathode of normal type will emit about 700 electrons/cm^2/sec. at 20°C., corresponding to a current of 1.1×10^{-16} amps/cm^2. In a tube of gain 10^7 and of cathode diameter 44 mm., this will give rise to a "dark current" at the output of 1.6×10^{-8} amp in the absence of any other contribution.

Unfortunately, owing to the fact that caesium has an appreciable vapour pressure at room temperature, ionisation will occur in the output section of the tube giving rise to both optical and ionic feedback, while stray electrons escaping from the dynodes, or produced from caesiated points, can cause fluorescence of the glass envelope which in turn gives rise to photoemission from the cathode. As a result of these processes, the dark current is always higher to some extent than would be expected from the thermionic emission of the photocathode and the discrepancy increases as the gain is increased by raising the voltage applied to the tube. This is illustrated in Fig. 5, which

/contd...

shows the dark current divided by overall gain as a function of tube gain. It will be seen that the "knee" of the curve occurs at higher values of gain in tubes with small cathodes and a large number of stages. When the very lowest light levels are to be measured, these facts must be borne in mind.

The reduction of thermionic emission by refrigeration of the tube will also reduce the feedback process, so that considerable improvement in dark current can be obtained by this means. Some tubes are specially made to withstand operation at liquid-air temperatures.

TIME CHARACTERISTICS OF PHOTOMULTIPLIER TUBES

The time delay in the secondary emission process itself is extremely short and has been estimated at about 10^{-14} sec., while an upper limit of 10^{-11} sec. has been determined experimentally.

The transit time delay is not of great importance in itself but is accompanied by a time dispersion which has considerable effect on the performance of a Photomultiplier tube and effectively sets a limit to the bandwidth of the device. This dispersion is greater in tubes with unfocused dynodes, since the variation in electron path length from dynode to dynode is greater here than in the focused type. Its effect is to convert a single electron at D_1 into an output pulse which varies with time in an approximately Gaussian fashion, but which rises more steeply and falls away more slowly than this would indicate. On the assumption of a Gaussian form for the dispersion, of standard deviation τ, the peak output current generated by a single electron incident on D_1 of a tube of gain N is $Ne/\tau\sqrt{2\pi}$, and there is thus a limit to the gain which can usefully be employed in a tube, since if the peak current for linearity (i) is produced by one electron at D_1, there is little advantage in exceeding a gain of $i\tau\sqrt{2\pi}/e$. If i is 10 mA and τ is 5×10^{-9} sec., then $N_{max} = 8 \times 10^8$. Values of τ are given in Table 11.

A further source of time spread lies in the finite size of the photocathode in an end-window tube since the time for an electron to reach D_1 from the centre of the cathode is much less than for an electron from the periphery. This may result in a further dispersion of between 10 and 30 mμsec., depending on the cathode size. E.M.I. high resolution tube type 9593 employs a concave photocathode combined with a focused dynode structure.

SIGNAL-TO-NOISE RATIO IN PHOTOMULTIPLIER TUBES

The main source of noise in a Photomultiplier tube results from the random nature of the photoemission which forms the primary signal. The process of secondary emission is also statistical and some primary electrons will produce more and some less, secondaries than the average value δ. It can be shown that this random element in the multiplication process will increase the statistical spread of the original signal, which has a r.m.s. value of $(Fn)^{\frac{1}{2}}$, where Fn is the number of photoelectrons collected in a given time t, by a factor equal to

$$\left[1 + \frac{1}{g_1\delta_1} + \frac{1}{g_1\delta_1}\left(\frac{1}{g\delta - 1} \right) \right]^{\frac{1}{2}}$$

/contd...

Here $g_1\delta_1$ is the gain of D_1 and $g\delta$ is the average stage gain of the rest of the tube. The fractional statistical spread due to the original n electrons, which is $n^{-\frac{1}{2}}$, is thus increased by a factor equal to

$$a = F^{-\frac{1}{2}} \left[1 + \frac{1}{g_1\delta_1} + \frac{1}{g_1\delta_1} \left(\frac{1}{g\delta - 1} \right) \right]^{\frac{1}{2}}$$

Typically F is 0.9, $g_1\delta_1$ is 6 and $g\delta$ is 4, so that a = 1.15, and the fractional standard deviation of the signal, σ, is equal to $a.n^{-\frac{1}{2}}$.

The value of n, the average number of photoelectrons produced at a time t, is given by

$$\frac{S.L. \times 10^{-6}.t.,}{e}$$

where S is the photosensitivity in µA/lumen, L is the light intensity in lumens and e is the electronic charge, 1.6×10^{-19} coulombs. The output current i is equal to G.S.L. amp., where G is the overall gain in millions, so

$$n = \frac{i.t. \times 10^{-6}}{G.e.}$$

and the fractional σ is equal to $1{,}000a\ (G.e./i.t.)^{\frac{1}{2}}$. Then, if a Photomultiplier tube measures a light level so low that with G = 10 million, i = 1 µA, and if the galvanometer has a time constant of 1 sec., the fluctuations to be expected in the reading will have a fractional r.m.s. value of

$$1{,}000 \times 1.15 \left[\frac{10 \times 1.6 \times 10^{-19}}{10^{-6}} \right]^{\frac{1}{2}} = 1.5 \times 10^{-3}$$

We find from statistical theory, that with this value of σ, a fluctuation of 1 per cent would occur only once in 20 years, but ½ per cent would be expected once every 6½ minutes.

If now an amplifier is used to observe the output current, we can take the integrating time to be 1/2f where f is the bandwidth, so the r.m.s. noise current, which would be $i\sigma$, is equal to $1{,}000\ i.a.\sqrt{Ge./i.t.} = 1{,}000a\ (2G.e.i.f.)^{\frac{1}{2}}$. The ratio of signal power to noise power is $1/\sigma^2$ and equals

$$\frac{i}{2.10^6.G.e.a^2.f} \quad \text{or} \quad \frac{SL.F.}{2 \times 10^6.f.e.a^2}$$

Thus, to maximise the signal-noise ratio, it is necessary to have S, the photosensitivity, as high as possible, and a, the noise enhancement factor, as low as possible. The latter is largely controlled by the collection efficiency and the first stage gain, $g_1\delta_1$, so it is desirable to keep the voltage between cathode and D_1 as high as allowable.

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APPLICATIONS OF PHOTOMULTIPLIER TUBES

The ability of a Photomultiplier tube to convert low levels of illumination into usable values of electric current, results in a number of applications of which perhaps the most obvious is the replacement of a photographic plate in such instruments as spectrophotometers. Two basic methods are used. In one of these a spectrum is scanned over a fixed Photomultiplier tube, the output of which is recorded on a chart moved in synchronism with the wavelength drum. In the other method a tube is fixed in the focal position of each spectrum line of interest. This technique requires the use of several tubes mounted along an arc of perhaps 6 ft. radius. The current from each tube in this instrument is allowed to charge a carefully chosen capacitor which is discharged when a preset voltage is attained, recharged, and so on, the number of cycles being recorded on a scaler and printed out at the end of a run. It is clear that this integrating technique does not require such a constant source of illumination as does the scanning method and gives a much more rapid response, which is of course attained at the expense of greater instrumental complexity. Another advantage of the multi-tube spectrometer is that each tube can be chosen to be the optimum for a particular wavelength. The scanner, on the other hand, requires a general purpose tube sensitive from the far red to below 2,000 A^{o}, such as is provided by a Bi-Ag-Cs cathode on a quartz window.

The statistical considerations, already mentioned, must be taken into account when the scanning rate or integrating time of these devices is fixed, as this factor sets one limit to the accuracy obtainable, although the ultimate sensitivity is of course controlled by the dark current of the tube and particularly by its stability.

When a photomultiplier is first switched on in its light-tight container, the dark current is found to be appreciably higher than its final, stable value and decays with time in a roughly exponential fashion. This phenomenon, which is more noticeable in red sensitive tubes, is probably due to a combination of effects, such as the stabilisation of the potential of insulators, including the interior surface of the envelope and the decay of any phosphorescence in the materials of tube construction. In order to maintain the dark current at a stable value, it is desirable during standby periods to keep a photomultiplier tube switched on, with a small auxiliary light source adjusted to give an output current comparable with that given by the tube when in use. A frequent cause of difficulty with dark current is connected with the mounting of the tube, particularly when the anode is run at earth potential. If the exterior of the tube envelope is not well insulated from earth, the glass can charge up sufficiently to extract electrons from the dynode system and cause a fluorescent patch on the wall with a consequent increase in dark current. A cure for this is to graphite the outside of the envelope, connect the graphite to the cathode and cover with polythene to provide insulation.

At the very lowest light levels, when it is perhaps necessary to refrigerate the tube in order to reduce the thermionic emission from the cathode and the vapour pressure of the caesium, the photo-current can be brought down as low as 20 electrons per minute. With a tube gain of 10^8, this would correspond to an output current of 5×10^{-11} amp, which is rather lower than the leakage currents generally experienced in Photomultiplier tubes. It is more convenient in this instance to count each electron individually, since each would

/contd..

give a pulse of about 0.5 V into a capacity of 30 μμF. (The statistics of multiplication put a spread on this amplitude and it would be necessary to count pulses of 0.05 V to get 100 per cent efficiency). By this means, it is not too difficult to detect 500 quanta per minute of blue light, corresponding to an energy level of 4 x 10^{-18} watts.

The ability of a Photomultiplier tube to respond to very short pulses of low-intensity light is used to its fullest extent in scintillation counters, the simplest example of which is the detection of the scintillations produced when alpha particles strike zinc sulphide phosphor. Each alpha particle expending an energy of 2 MeV in ZnS-Ag, gives a light flash which can produce 4,000 photoelectrons and so give an output pulse of 20 volts from a Photomultiplier tube having a gain of 10^6. Such combinations of Photomultiplier tube and ZnS phosphor are widely used in portable probes used for monitoring work benches and clothing for alpha contamination.

Perhaps the most elegant technique in the scintillation counter field is that of gamma-ray spectroscopy. This utilises the fact that a large clear crystal of a material such as sodium iodide activated with thallium, will give a light output which is closely proportional to the energy dissipated in it by an electron produced by a scattered gamma ray, which may transfer either part of its energy by Compton scattering, or the whole of its energy by photoelectric absorption. The pulses appearing at the output of a photomultiplier tube coupled to such a crystal may be sorted out in amplitude by a pulse height analyser (or kick-sorter) to give a curve as in Fig.6, which shows the spectrum from Co^{60} gamma rays. The two photoelectric peaks at 1.1 and 1.3 MeV stand out clearly from the Compton continuum. The curve of Fig.6 was obtained with a scanning kick-sorter, but multi-channel kick-sorters are also available and can be set to record the counts occurring at a particular energy as in the integrating type of multi-tube spectrometer.

The resolution obtainable in a scintillation gamma-ray spectrometer depends on the parameter a $(n)^{-\frac{1}{2}}$ (see above) and n in turn is proportional to the gamma-ray energy, the efficiency of the crystal and the photosensitivity of the Photomultiplier. A useful measure of the performance of a given tube and crystal is the percentage width at half amplitude of the photoelectric line at 661 keV from Cs^{137} which, with E.M.I. 2" end-window tubes and 1½" diameter NaI-Tl crystals, is about 8.5 percent on the average.

The other main use of Photomultiplier tubes can be classified as a transducer application, of which a typical example is the flying-spot scanner used in television. A high brightness cathode-ray tube focussed onto a transparency, from which the transmitted light falls onto a Photomultiplier tube. The c.r.t. brightness and optical system are usually arranged so that an output current of 1 mA is obtained for peak white with a Photomultiplier tube working with a gain of 10,000. From the section on signal-to-noise ratio and assuming that a is 1.15, the signal-to-noise ratio to be expected under these conditions would be $34 - 10.\log_{10}(G.f)$dB, which is 45.3 dB for G = 0.01 and f = 7.5 Mc/s. When this arrangement is embodied in a colour film scanner, three Photomultiplier tubes are used, one of which is red sensitive, the light from the transparency being divided according to colour by three dichroic mirrors.

/contd...

Another interesting transducer application also uses a flying-spot c.r.t. but the transmitted light is focussed upon photographic printing paper. The amount of light reaching the paper is measured by a Photomultiplier tube, which feeds back to the grid of the c.r.t. in a predetermined fashion to compensate for excessive density or transparency of the negative being scanned. By this means a controllable gamma can be achieved which results in greatly improved prints from inferior negatives.

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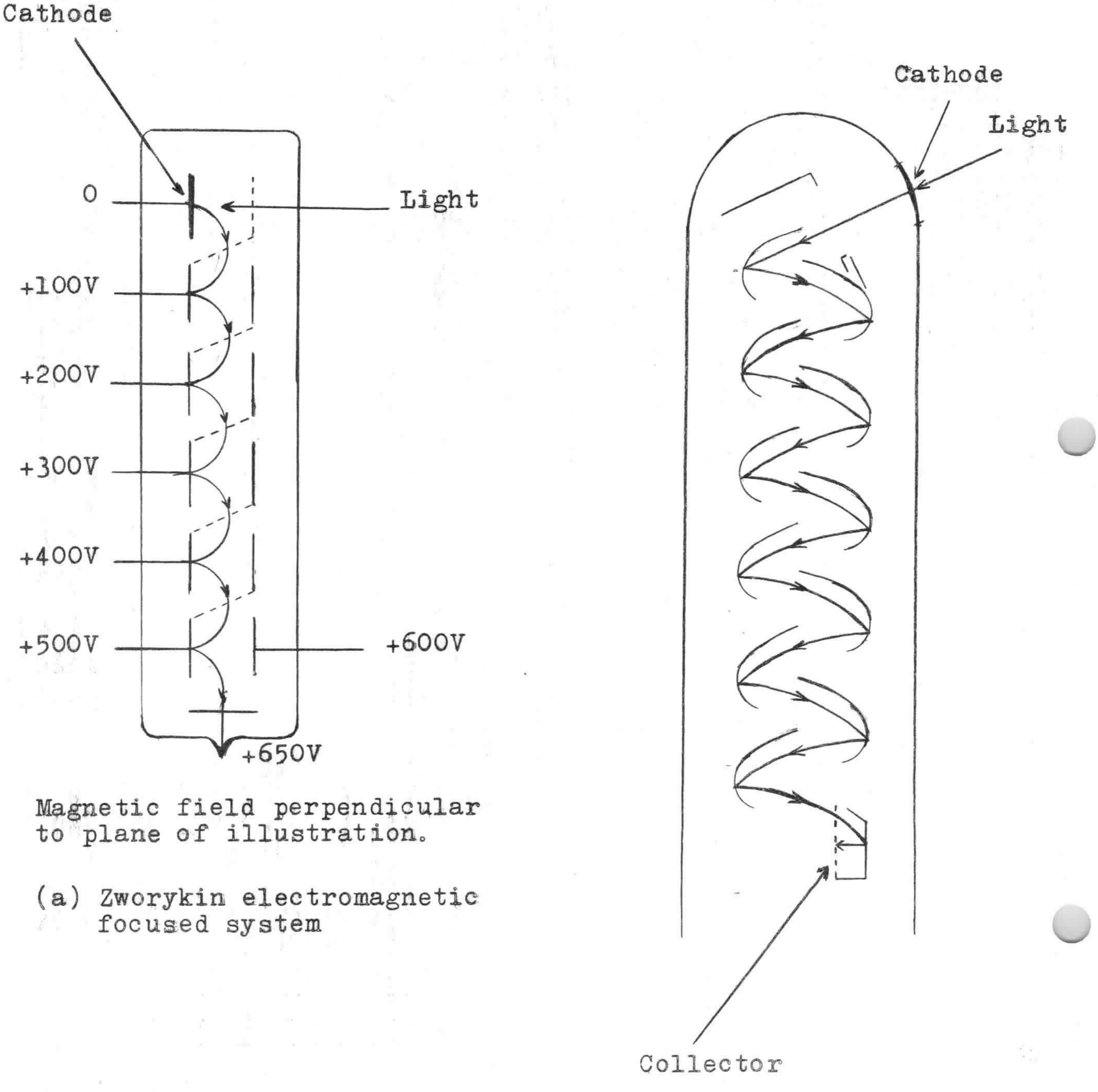
FIG. 1. Focused dynode photomultiplier tubes.



Magnetic field perpendicular to plane of illustration.

(a) Zworykin electromagnetic focused system

(b) Rajchman linear electrostatic focused system.

Fig. 2. Unfocused dynode photomultiplier tubes.

(a) Venetian blind (b) Box and grid

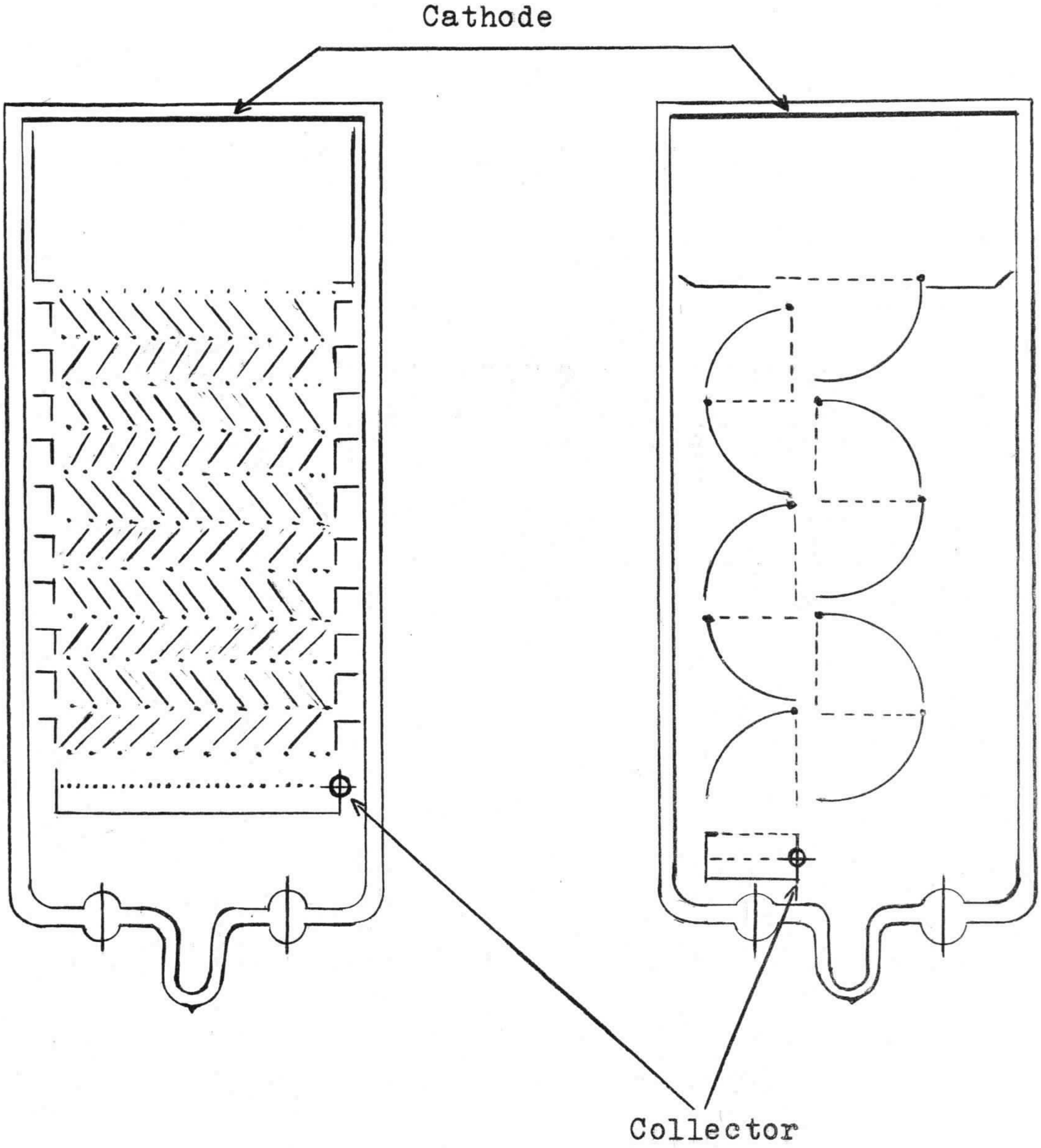
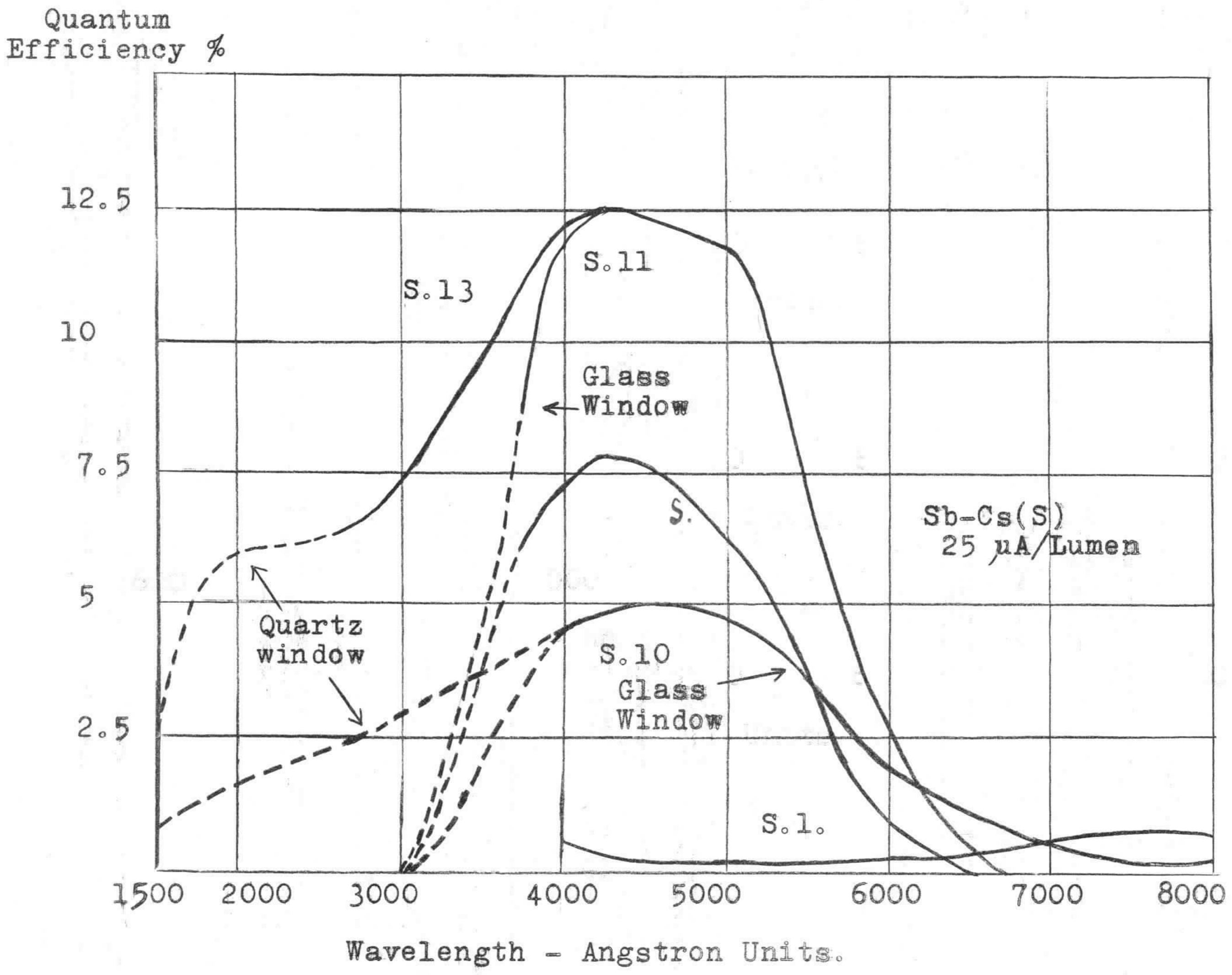


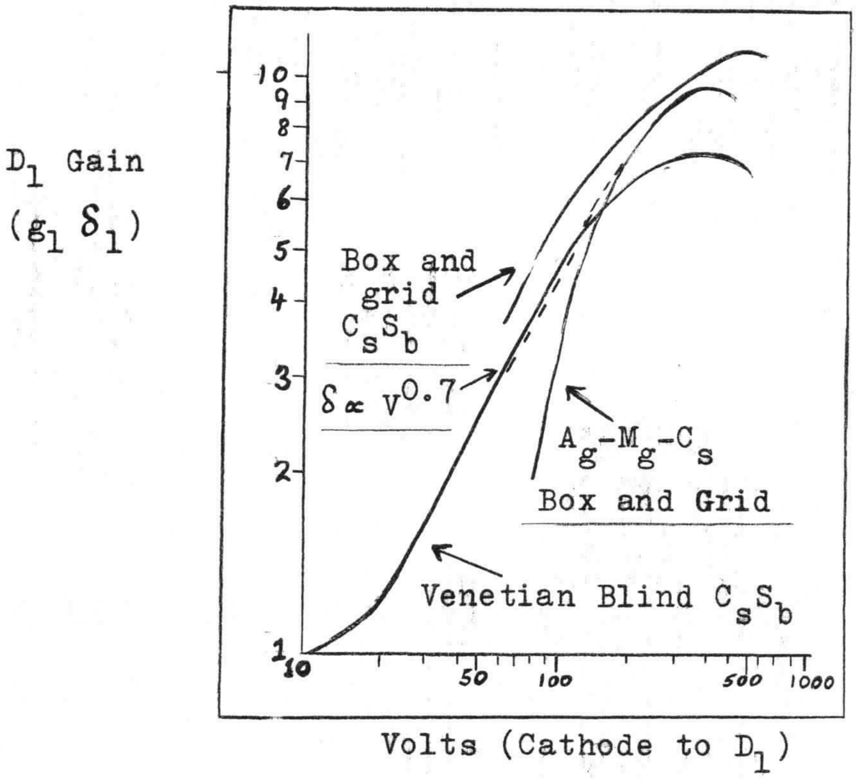
Fig. 3. Spectral sensitivity curves for various photosensitive cathodes.



S.1. Cs-O-Ag.
S.10. Bi-Ag-Cs (30 µA/Lumen)
S.11. Sb-Cs (50 µA/Lumen)
S.13. Sb-Cs In Quartz (50 µA/Lumen)

Curves are for typical photocathodes with photosensitivities (to tungsten light, 2854°K) as shown, corrected to equal energies of incident light at each wavelength. Peak height for each type is proportional to photosensitivity.

Fig. 4. Variation of secondary emission coefficient with electron energy.



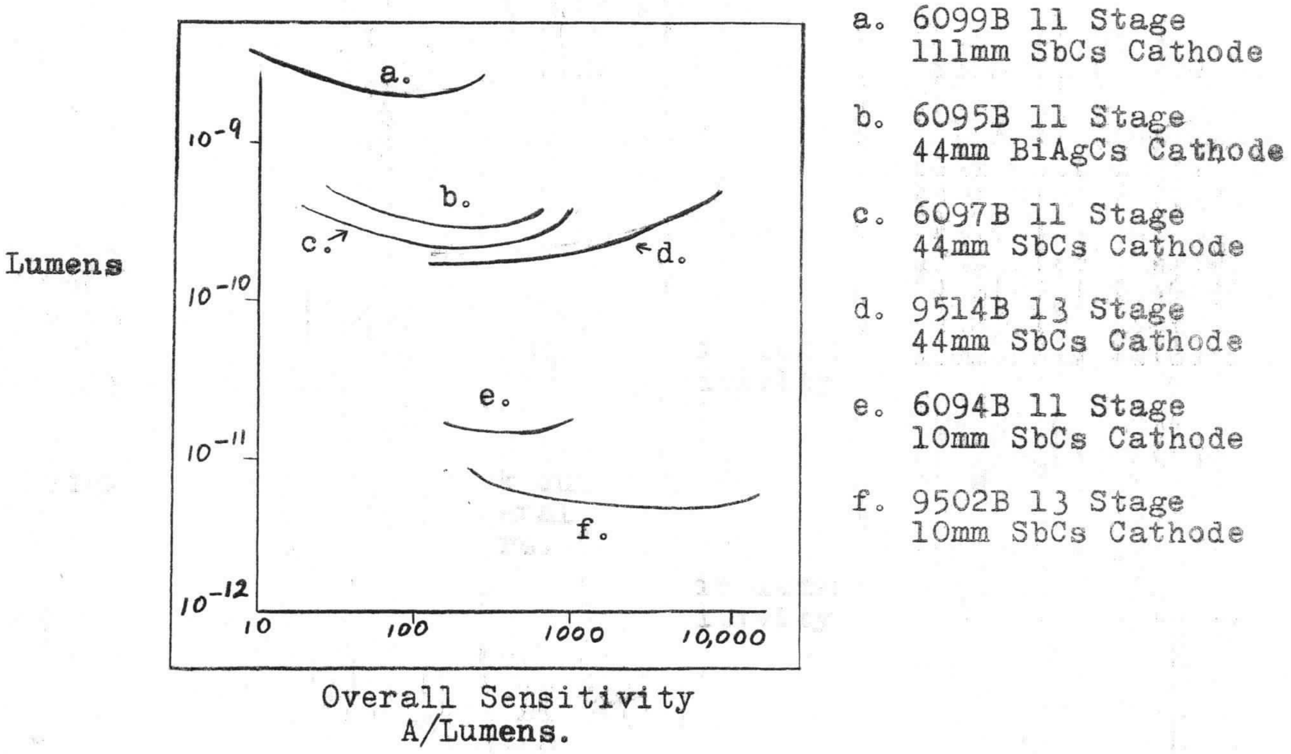


Fig. 5. Equivalent dark current in lumens, as a function of overall sensitivity in photomultipliers.

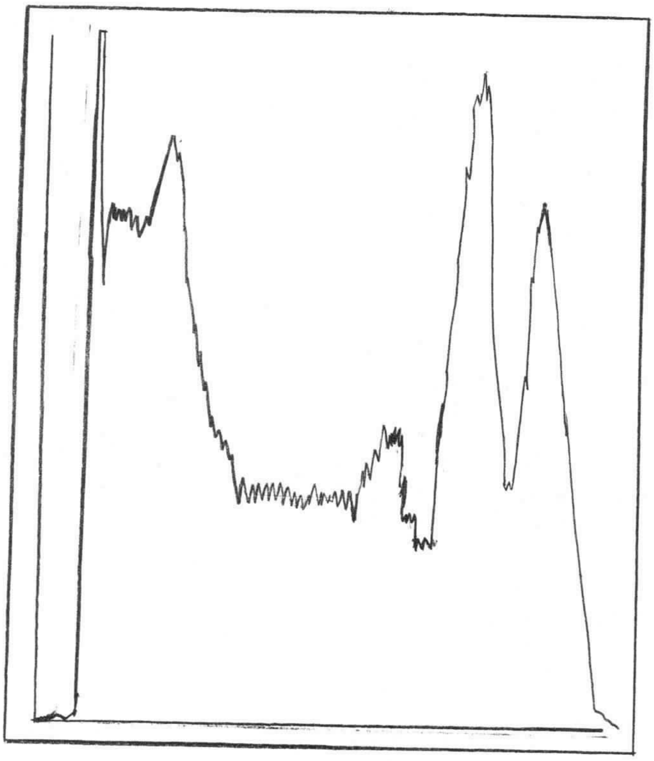


Fig. 6. Scintillation spectrum of Co^{60} gamma rays taken with 4.5-in. NaI(TI) crystal and 5-in. 6099B photomultiplier tube.

Table 1. OUTPUT CHARACTERISTICS OF E.M.I. PHOTOMULTIPLIER TUBES.

Dynode Type	Typical Tube Type	Peak Anode Current (la)	Voltage between anode and last dynode for 90% of la
Linear focused type.	9593	800 mA 500 µA	-- 60V
Venetian blind	6097	15 mA 400 µA	46V 22V
Box and grid	9524	7.5 mA 1.5 mA 300 µA	100V 90V 50V

Table 2. TIME CHARACTERISTICS OF E.M.I. PHOTOMULTIPLIER TUBES

Tube Type	No. of Stages	Overall Voltage (V)	Gain	Time spread (width at half amplitude ≠ 2.36γ)
9593 (Linear focused dynode)	14	2,000	10^8	4×10^{-9}
6097 (venetian blind dynode)	11	1,920	2×10^7	18×10^{-9} sec.
9524 (box and grid dynode)	11	1,600	4×10^7	20×10^{-9}

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STABILITY OF PULSE HEIGHT WITH COUNT RATE

E.M.I Photomultiplier tubes recommended for gamma ray spectroscopy have dynodes coated with a caesium antimony secondary emitter, which has relatively low resistivity compared with the Ag-MgO-Cs layer used in some other tube types. P.R.Bell (Rev. Sci. Inst. 26 726, 1955), showed that tubes having Ag-MgO-Cs dynodes showed a marked variation in pulse height with count rate, while Cs-Sb surfaces were relatively free from this defect.

Tests on E.M.I types at A.E.R.E Harwell over several years have confirmed this superiority, which may be illustrated by the following experiment:

A 6097B operated in a spectrometer at relatively high gain (around 3 x 10^6) was set up with a dynode resistor chain current of 125 uA and a Zn^{65} (1.12 MeV) gamma ray peak was set at channel 50 on a multichannel analyser (Back bias 28 V. Channel width 0.3 V, so 1 channel = 0.7% of Zn^{65} peak). The anode current under the above conditions was 0.6 µA. A Cs^{137} (0.661 MeV) source was then brought up to the crystal to give a count rate that saturated the equipment and an anode current of 3 µA (between 10^5 and 10^6 counts per second) The Zn^{65} peak then shifted from channel 50 to channel 52 over a period of 5 minutes and was stable thereafter. The total shift was 1.4% for count rate conditions which would not be used in practice. Under these conditions no attempts have been made to plot peak shift with useable count rates as the shift is too small to measure with accuracy. (At a lower gain, 3 x 10^5, the pulse height shift was negligable).

Similar results would be given by E.M.I types 9524, 9536, 9514, 9531, 9578, 9530, 9579, 9583, 9584, 6255 and 9545.

GAIN STABILITY OF E.M.I PHOTOMULTIPLIERS

The report given below is extracted from a letter sent to us by a company in the USA who carried out evaluation of gain stability of E.M.I tubes type 9536 with those of a competitive type:

"Two E.M.I type 9536B multiplier phototubes were received on loan for testing and evaluation. The results of these tests show the E.M.I type 9536B to be far superior to an American manufacturer's type using silver magnesium dynodes. To date, gain stability measurements have been made on 3 type 9536B and 2 American multiplier phototubes. The average gain drift for the type 9536B multiplier phototubes was .64% per day, after an initial twenty four hour stabilising period. The American multiplier phototubes average daily gain drift was 12%, thus making them entirely unsatisfactory for our application.

"The daily gain drift of a multiplier phototube seems also to be a measure of the gain shift to be expected following large input signal changes to the multiplier. This gain shift is consistantly lower than .2% with the type 9536B, but amount to as much as 30% with the American type."

JS/PR
28.6.60

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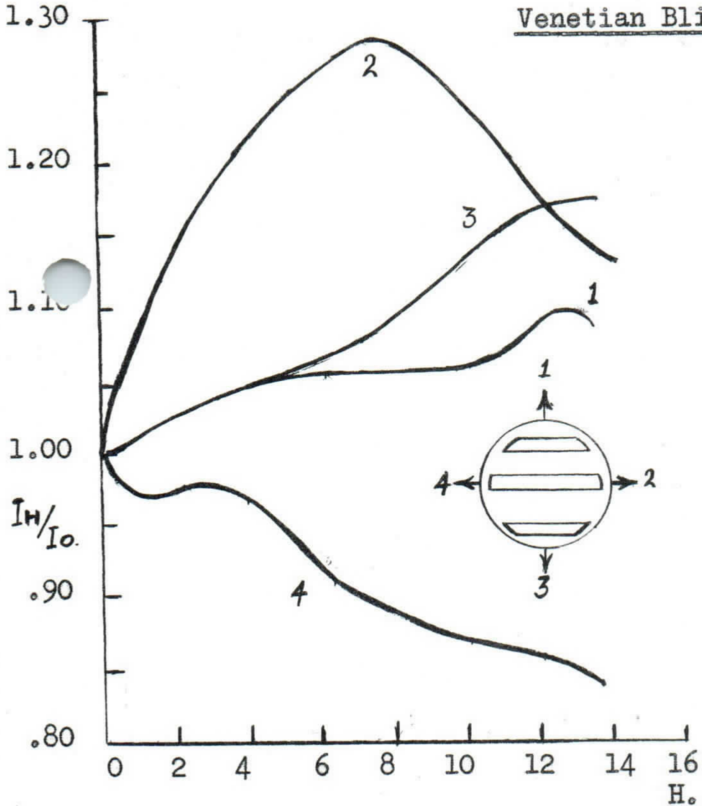
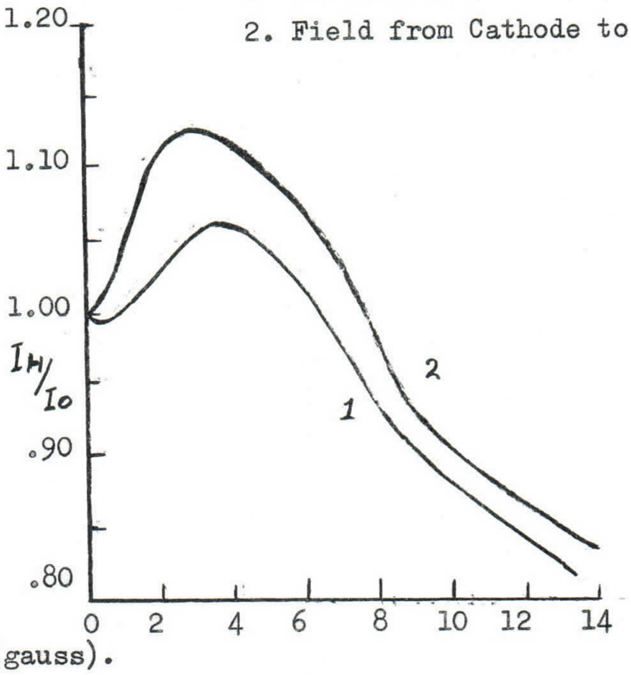
EFFECT OF MAGNETIC FIELD ON PHOTOMULTIPLIERS

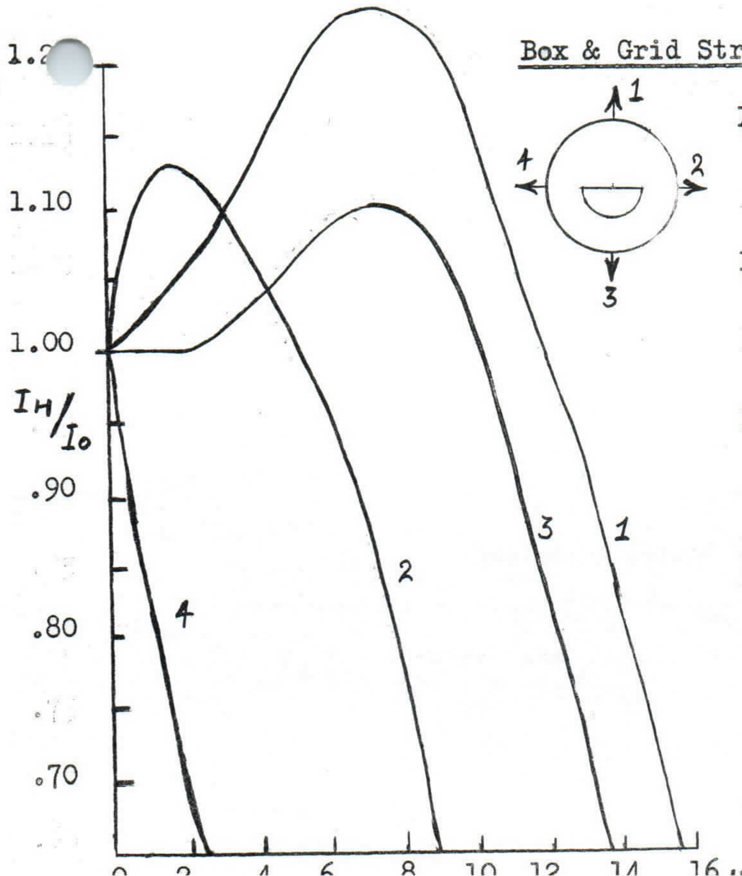
Venetian Blind Structure - Photomultiplier type 6097B

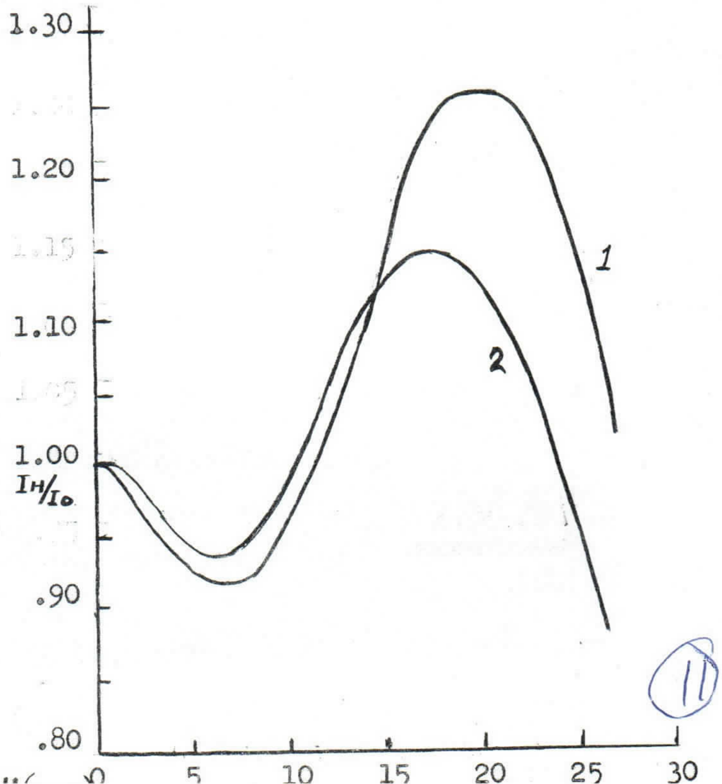
1. Field from Anode to Cathode
2. Field from Cathode to Anode





Box & Grid Structure - Photomultiplier type 9524B





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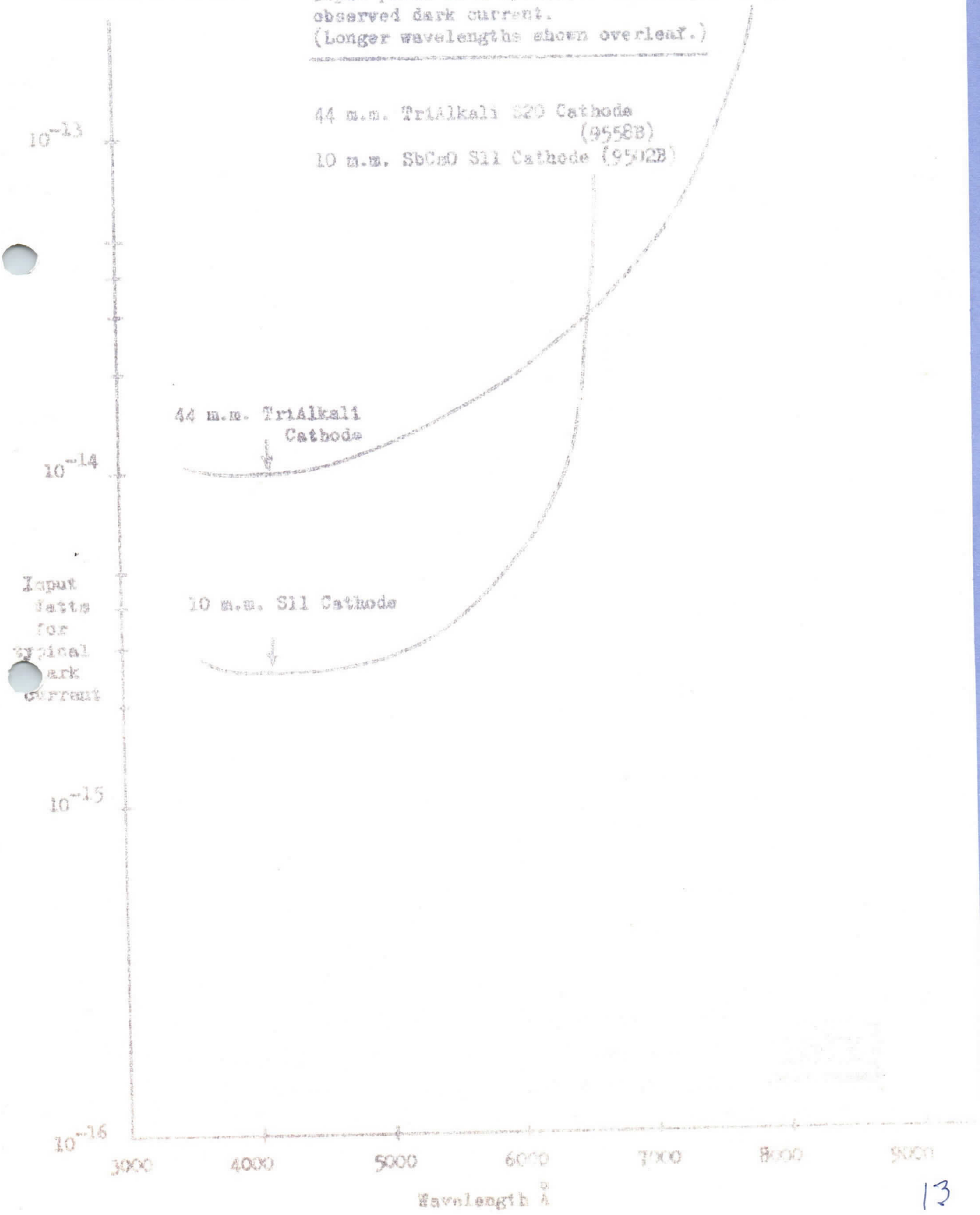
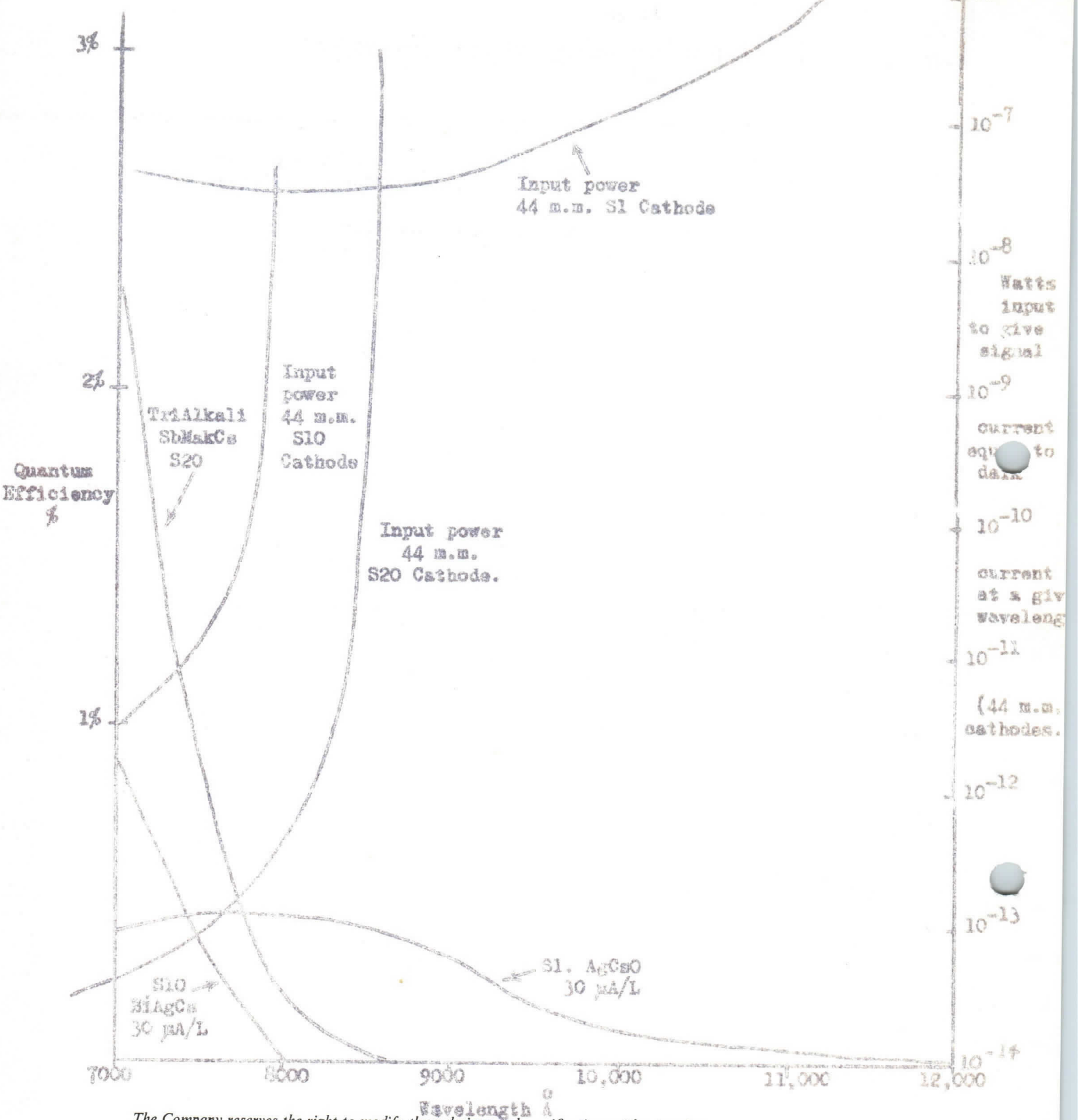
Dark Current Characteristics as a function of input power at a specified wavelength to give observed dark current.
(Longer wavelengths shown overleaf.)



Red Sensitive Cathodes



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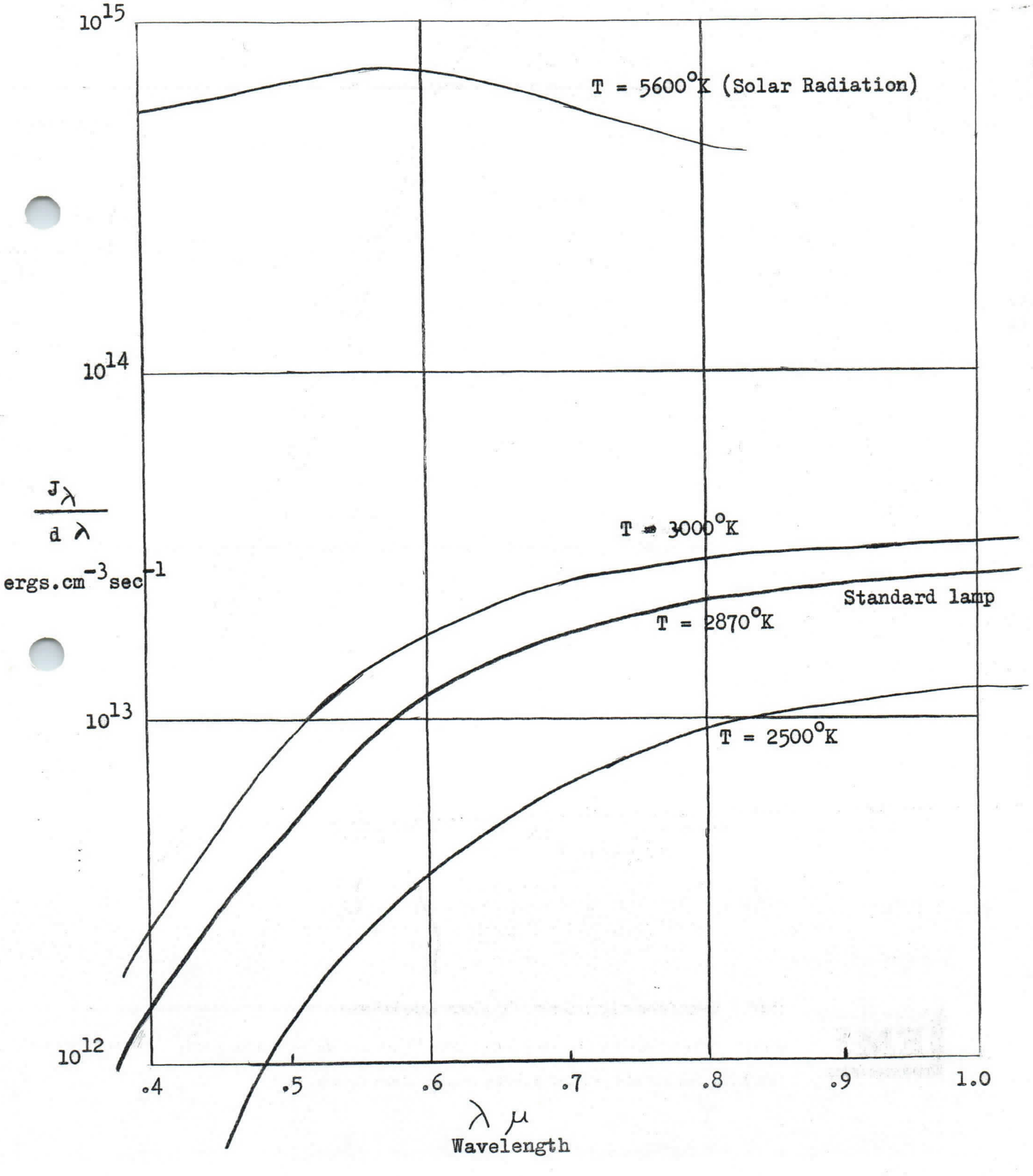
Spectral distribution of power emitted from black bodies, at various temperatures.



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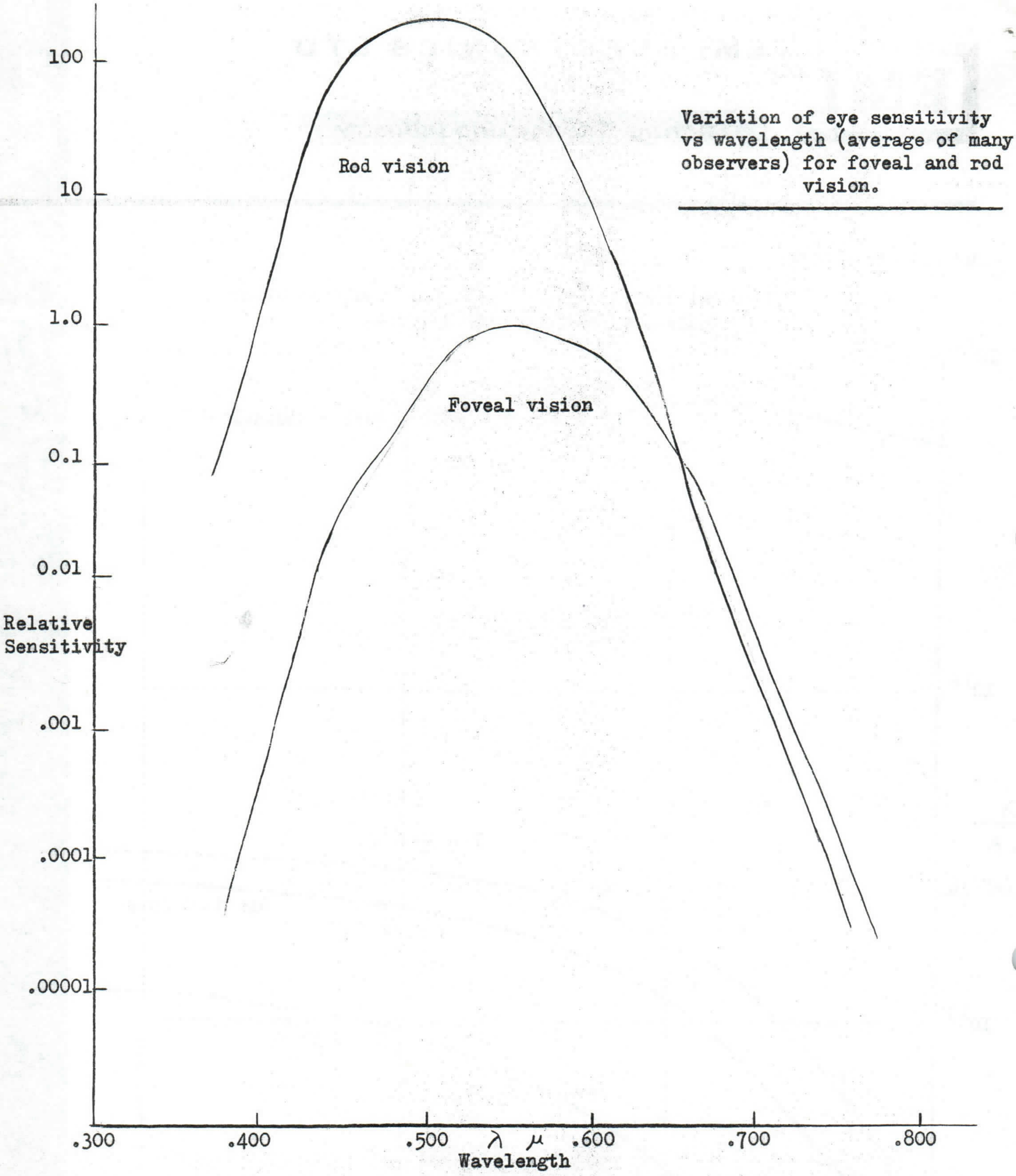

Variation of eye sensitivity vs wavelength (average of many observers) for foveal and rod vision.

EC8/44
19.10.60.

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PROGRESS IN PHOTOMULTIPLIER TUBES, SCINTILLATION INSTRUMENTS AND IMAGE INTENSIFIERS

J. SHARPE - E.M.I. ELECTRONICS LTD.

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Summary: Reviews recent work at E.M.I. on Photomultiplier tubes for tritium counting and for other specialised purposes, including short resolving time applications. Data on spread of parameters for production tubes of various types are also given. Details of health physics instruments, based on scintillation techniques, briefly outlined and a new tube designed for these, is described. Work on image intensifiers is also in progress.

1. PHOTOMULTIPLIER TUBES FOR TRITIUM COUNTING

In the two years since the last report on E.M.I. Photomultipliers was made to this Symposium, more experience on the production of tubes for tritium counting has been obtained and this has provided much better understanding of the processing parameters. The types involved are the 2" venetian blind tubes, type 9514S (13-stage), 6097S (11-stage) and 9536S (10-stage) and the $1\frac{1}{8}$" box and grid tube type 9524S, all of which have SbCs cathodes processed for minimum red sensitivity and dark current.

In order to monitor production quality it has been necessary to institute an operational test using a sealed liquid scintillator cell, containing tritium, operated in a test jig above a shutter beneath which is mounted the tube under test. The geometry of source, shutter and tube window is rather worse than would be used in an analytical instrument. No gamma ray shielding is employed and the assembly is operated at ca. 23°C. Each tube is operated at its appropriate overall sensitivity (e.g. a 9514S at 2000 A/L) and a period of an hour for recovery from the brief light exposure is allowed before the count rate is set at 90 counts per second. The count rate due to the tube itself is then observed when the shutter is closed and the performance expressed as a ratio, e.g. 90/15. This measurement is then repeated after a further hour in order to check the rate of improvement with soaking.

Fig. 1 gives the correlation of this empirical rating with dark current for a batch of 9514S tubes and, while the expected trend is shown, there is nevertheless sufficient spread to make the tritium test extremely useful, while Fig. 2 shows that the voltage of operation is not critical.

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In a recent check by B. Caddock at the Thornton Research Centre, using a counting head shielded by 1" of steel and stabilised at 20°C, with a tube-shutter-cell geometry rather better than that used in our test jig, a counting efficiency for tritium of 14% was obtained for a tube background of 190 counts per minute, on a 6097S rated at 90/5, while an earlier tube rated at 90/7 gave an efficiency of 12% (see Fig. 3) In the same apparatus, a 6097 F having a conventional S-11 cathode, gave an efficiency of 2% for the same background. (1) At -20°C the 6097S would be expected to give a tube background of about 20 counts/min. for an efficiency of 15%.

At the present time, between 15 and 20% of tubes made with the present technique are rated as 90/5 or better, while more than 60% are 90/10, or better.

2. GENERAL TUBE PROGRESS

The dark current vs. overall sensitivity curves for various tube types, including 9514S, given in Fig. 4, indicate the improvement in performance which has been gained by the experience in making S cathodes, even in tubes with a normal S-11 surface, while table 1 summarises typical performance in other parameters and Fig. 5 gives some idea of typical production statistics.

In view of the high cathode efficiency and low dark current of trialkali cathode tubes type 9558B, it was hoped that good tritium counting results would be obtained, but a typical tube, having a photosensitivity of 150 uA/L and an equivalent dark current of 10^{-11} lumens, gave a rating of 90/25, which compares rather unfavourably with the specially made S cathode tubes.

A few tubes similar to type 9558, but with 11 dynodes of oxidised Ag-Mg, have been made with modified cathodes which have so far given photosensitivities not greater than 25 uA/L and extremely low values of gain, requiring 3000 V for 25 A/L. The dark current of these tubes is rather low, and at room temperature is masked by a leakage of about 10^{-9} amps. No. difference in this reading is obtained at a temperature of 100°C, but at 150°C the dark current at 25 A/L rises to 0.05 uA. The gain itself changes very little with temperature.

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The low gain of these tubes makes it difficult to obtain useful tritium counting performance, but their extremely low temperature coefficient and ability to withstand elevated temperatures should recommend them for use in well logging applications.

3. INSTRUMENTS AND RELATED TUBES

The technique of scintillation counting is exploited in health physics instruments produced by E.M.I. Electronics and in particular the use of a plastic phosphor coated with ZnS-Ag, for the simultaneous detection of alpha and beta particles.

The Hand and Clothing monitor, (2) HC-1, shown in Fig. 6, employes four 5" Photomultiplier tubes type 9530 in counting units of sensitive area 5" x 8", having light-tight windows of aluminised mylar over the dual phosphor mentioned above. By the use of stable, low level, vacuum tube discriminators, adequate separation of pulses due to alphas and betas is obtained, with an overall efficiency of detection of more than 30% for Sr^{90} and more than 17% for Pu^{239}. A fifth unit, employing a thicker plastic phosphor, is used for background cancellation in intensities up to 0.5 mr/hr.

A dual phosphor bench probe, of 50 cm^2 sensitive area and using a $1\frac{1}{8}$" tube type 9524, as shown in Fig. 7a, is operated by a portable, battery operated, transistor circuit unit (Fig. 8) which has a unique audio monitor giving tone differentiation between alpha and beta particles. In the scintillation probe illustrated, the sensitive area is limited by that of the tube photocathode, but requirements of convenience forbade the use of a tube of greater diameter. A special Photomultiplier tube, type 9600, has therefore been produced, as shown in Fig. 9, which has considerable side-wall sensitivity to give an effective cathode area of ca. 20 cm^2, compared with the end window area of 4 cm^2, and this, used in the geometry of Fig.7b, gives a 100 cm^2 probe area, with a handle whcih extends parallel to the sensitive surface to give a total instrument depth of $2\frac{1}{2}$".

For gamma ray spectrometers, analysis of available data shows that the resolution obtainable for a gamma ray of energy E eV, in a good quality sodium iodide crystal on a Photomultiplier tube having an S-11 cathode of photosensitivity P uA/L, with good uniformity and electron collection into D1, is approximately:

$$\Delta, \text{ (width at half maximum)} = 100 \left(\frac{90{,}000}{EP} + \frac{3.3}{E^{\frac{1}{2}}} \right)^{\frac{1}{2}} \%$$

The effect of tube photosensitivity is only secondary for high energy gammas, owing to the inherent crystal spread, but becomes of considerable importance for the low energy region, as will be seen from Table 2. Thus, for scintillation detectors of the Pu^{239} 17 keV Xray, we have found it necessary to supply 9524A tubes, with a minimum photosensitivity of 80 uA/L and a maximum equivalent dark current of 10^{-11} lumens. The latter requirement is dictated by the necessity to operate at a low discriminator level without undue tube background.

/cont....

For gamma rays of reasonable energy, a 3" NaI-Tl crystal potted by Hilger and Watts onto a selected 3½" photomultiplier tube, type 9531A, (Fig.10 and Fig.11) gives a peak to valley ratio for Co^{60} of 4:1 or better (corresponding to a Cs^{137} resolution of ca. 7½%).

For low background counting assemblies, both 3½" and 5" tubes, type 9531Q and 9530Q, have been made with quartz envelopes. The quartz part of the neck is made as long as possible but a graded seal must then be inserted to match up with a Kovar sealing glass for the tube base. This glass unfortunately contains 4% K_2O as well as the normal small amount of radium. As a result, the gain in background is much greater for the 5" tube than for the 3½" and on a 7" crystal the former gives an improvement of about 5 over normal tubes, while an assembly of three 3½" tubes (to give comparable counting efficiency), gives only a factor of about 2. Some improvement could doubtless be obtained by increasing the neck length of the smaller tube.

4. FAST TUBES

A fast tube, type 9593, has been introduced recently and this gives a rise time of about 2½ musec with a linear anode current of 200 mA, at an overall voltage of 2500 V. (Fig. 12). Essentially similar in geometry to the RCA 7264, modifications have been made enabling higher voltages to be applied in order to obtain a slight reduction in rise time. The tubes are routinely tested with a dynode chain uniform from D1 to D11 and then graded up to a factor of 2 for anode to D14. Investigations by R.B. Owen and D. Smout at A.E.R.E. Harwell have shown, however, that the dynode voltage distribution can be adjusted for an optimum which is different from tube to tube and which then results in a minimum rise time of 1.7 musec, with a time spread of 4.2 musec. It seems important to provide as high voltage as possible between Anode and the last dynode.

In parallel with work on the 9593, which is essentially aimed at establishing production techniques with a geometry presenting problems different from those of our main tube line, fundamental work by J.A. Lodge and P. Muff of E.M.I. Research Laboratories has been directed towards an understanding of the limiting performance which can be expected from tubes of not outrageously unconventional design.

Two Cathode - D1 geometries, corresponding to commercially available tubes, are shown in Fig. 13 a and b and the relevant parameters are tabulated in Table 3. It will be seen that when the finite energy of emission of photoelectrons is taken into account, the field at the cathode becomes the controlling factor in reduction of time spread. With this in mind, the E.M.I. geometry of Fig. 13c was developed, which employs a specially made curved, low interception, grid, with the results tabulated. The grid is operated at D1 potential.

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5. IMAGE INTENSIFIERS

Over the past 20 years, E.M.I. has been involved in the design and manufacture of image transformer tubes of one sort or another and has naturally taken great interest in the recent requirements of the nuclear physicist. Up to a few months ago, work has been directed onto the multistage photosurface - phosphor combination with which reasonable results had been achieved. The publication of the achievements by Wilcox at Imperial College of an operational transmission multiplier has naturally resulted in the re-orientation of this phase of our work. Many of the techniques previously developed and in particular those for background reduction, are being applied to the new programme but at the present time I am unable to provide the meeting with clear-cut performance data and can only confirm our activity in this field.

ACKNOWLEDGEMENTS:

The work reported in this paper has been carried out by E.E. Thomson and V.A. Stanley at Ruislip and by J.A. Lodge and P. Muff at Hayes.

It is a pleasure to acknowledge the co-operation of R.B. Owen of A.E.R.E. and B. Caddock of Shell Research Ltd., in our work.

Thanks are also due to the Directors of E.M.I. Electronics Ltd., for permission to present this paper.

REFERENCES:

(1) The tritium standard was 2 uc/g Hexadecane - 1:2T obtained from the Radiochemical Centre at Amersham, counted in a 10 ml sample of toluene plus 5 g/litre p-terphenyl plus 16 mg/litre POPOP, in a hemispherical silvered vial. The blank test gave a total background of 300 c.p.m.

(2) J.R. Brown - Simultaneous Hand and Clothing checking for alpha and beta contamination. 2nd U.N. Geneva Conference (Paper P/294UK)

TABLE 2

Effect of Photosensitivity on resolution

ρ uA/L	90	60	30
Δ for E = 10^6 eV	6.6%	7%	7.9%
Δ for E = 10^4 eV	36.5%	42.5%	58%

Studies of the time spread in the dynode systems associated with the two C-D1 geometries a and b, are summarised in Table 4 and show that the main problem lies in the D1-D2 region. An E.M.I. geometry to go with the gridded C-D1 system has been designed and ray tracing gives the results tabulated. It will be realised that investigations of this kind, neglecting the finite emission energy of the secondary electrons and utilising analogue plotting methods can only give approximate results, but it is felt that the comparisons made in tables 3 and 4 are likely to be of first order significance.

At the time of writing, only components of geometry c have been tested and a complete tube has not been made. It is expected an inherent rise time of ½ musec will be achieved and that work on the anode system, in too embryonic state to report, will maintain this time resolution at rather high output currents.

TABLE 3

Max. transit time differences for electrons at D1 originating with finite emission energy from different parts of the cathode. Cathode to D1 voltage: 300 V.

Geometry	a	b	c	
Zero emission energy	0.7×10^{-9}	1.3×10^{-9}	0.08×10^{-9}	sec.
1eV energy at 45° to normal only	0.5	1.7	0.13	
Both groups of electrons	2.2	1.9	0.14	
Fields at photocathode	12.5 V/cm	32 V/cm	450 V/cm	

TABLE 4

Transit time differences for electrons originating from opposite edges of the useful area of D1. Zero emission energy and 150 V/stage

Geometry	a	b	c	
D1-D2	2.9×10^{-9}	2.5×10^{-9}	0.9×10^{-9}	sec.
D2-D3	2.3	1.8	0.6	
D3-D4	3.1	2.0	0.7	
D4-D5 et seq.	2.7	2.1	0.8	
Field at useful part of dynode surface.	33-39 V/cm	40-45 V/cm	40-45 V/cm	

/contd.....

TABLE 1

Typical parameters of E.M.I. tubes for Scintillation Counting

Type	6097B	6097G	6097S	9514B	9514S	9536B	9536S
Description	11 Ven. blind SbCs	11 Ven. blind SbCs	11 Ven. blind SbCs	13 Ven. blind SbCs	13 Ven. blind SbCs	10 Ven. blind SbCs	10 Ven. blind SbCs
Base	15 pin glass	15 pin glass	15 pin glass	15 pin glass	15 pin glass	Diheptal	Diheptal
Window diameter	51 mm.	51 mm.	51 mm.	51 mm.	51 mm.	51 mm.	51 mm.
Cathode diameter	44 mm.	44 mm.	44 mm.	44 mm.	44 mm.	44 mm.	44 mm.
Cathode type	S-11	S-11	'S'	S-11	'S'	S-11	'S'
Cathode sensitivity (Median)	70 uA/L	70 uA/L	45 uA/L	70 uA/L	45 uA/L	70 uA/L	45 uA/L
Cathode sensitivity (Minimum)	40 uA/L	40 uA/L	25 uA/L	40 uA/L	25 uA/L	40 uA/L	25 uA/L
Overall sensitivity or gain (G)	200 A/L	200 A/L	200 A/L	2000 A/L	2000 A/L	50 A/L	50 A/L
Overall voltage V. (Median)	1370 V	1250 V	1600 V	1400 V	1600 V	1300 V	1600 V
Equivalent anode Dark Current L_D, input lumens: Median	2 x 10^{-11}	10^{-11}	3 x 10^{-12}	2 x 10^{-11}	2 x 10^{-12}	10^{-10}	10^{-11}
" " " Maximum	2.5 x 10^{-10}	10^{-10}	-	2.5 x 10^{-10}	-	10^{-9}	-
'G'	2000 A/L	2000 A/L		100,000 A/L		200 A/L	
'V'	1850 V	1700 V		2700 V		1600 V	
L_D Median	2.5 x 10^{-10}	10^{-10}		5 x 10^{-11}		10^{-10}	
Output current (linear)	50 mA	50 mA		50 mA		50 mA	
Rise time	7 musec	7 musec		8 musec		6 musec	
Time spread	14 musec	14 musec		16 musec		14 musec	
				Also available with quartz window as 6255B		Also available with quartz window as 9552B	

/contd...

TABLE 1 (contd)

Typical parameters of E.M.I. tubes for Scintillation Counting

Type	9530B	9545B	9524B	9524S	9600B	9558B	9593B
Description	11 Ven. blind SbCs	11 Ven. blind SbCs	11 Box/Grid SbCs	11 Box/Grid SbCs	11 Box/Grid SbCs	11 Box/Grid SbCs	14 Focused SbCs
Base	15 pin glass	15 pin glass	14 pin glass	14 pin glass	14 pin glass	20 pin glass	20 pin glass
Window diameter	170 mm.	360 mm.	28.6 mm.	28.6 mm.	28.6 mm.	51 mm.	51 mm. curved
Cathode diameter	127 mm.	310 mm.	23 mm.	23 mm.	End/Side wall sensitivity	44 mm.	42 mm.
Cathode type	S-11	S-11	S-11	'S'	'S'	S-20	S-11
Cathode sensitivity (Median)	60 uA/L	50 uA/L	70 uA/L	45 uA/L	45 uA/L	145 uA/L	60 uA/L
Cathode sensitivity (Minimum)	35 uA/L	30 uA/L	40 uA/L	25 uA/L	25 uA/L	100 uA/L	30 uA/L
Overall sensitivity or gain (G)	200 A/L	200 A/L	200 A/L	200 A/L	200 A/L	200 A/L	2000 A/L
Overall voltage V. (Median)	1450 V	2000 V	1150 V	1400 V	1250 V	1700 V	2500 V
Equivalent anode dark current L_D input lumens: Median	2 x 10^{-10}	2 x 10^{-10}	3 x 10^{-11}	3 x 10^{-12}	10^{-10}	2 x 10^{-11}	5 x 10^{-10}
" " " Maximum	2.5 x 10^{-9}	2.5 x 10^{-9}	2.5 x 10^{-10}	-	-	2.5 x 10^{-10}	-
'C'	-		2000 A/L		-	-	
'V'	-		1600 V				
L_D Median	-		4 x 10^{-11}				
Output current (linear)	50 mA	50 mA	10 mA				200 mA
Rise time			-				2.5 musec
Time spread	SLOW	SLOW	20 musec				4.5 musec
	Also available in quartz envelope as 9530Q		Also available with quartz window as 9526B				

CORRELATION BETWEEN DARK CURRENT AND THERMIONIC
BACKGROUND FOR SPECIFIED COUNT RATE
FROM H^3 SCINTILLATION SOURCE IN STANDARD TEST JIG.

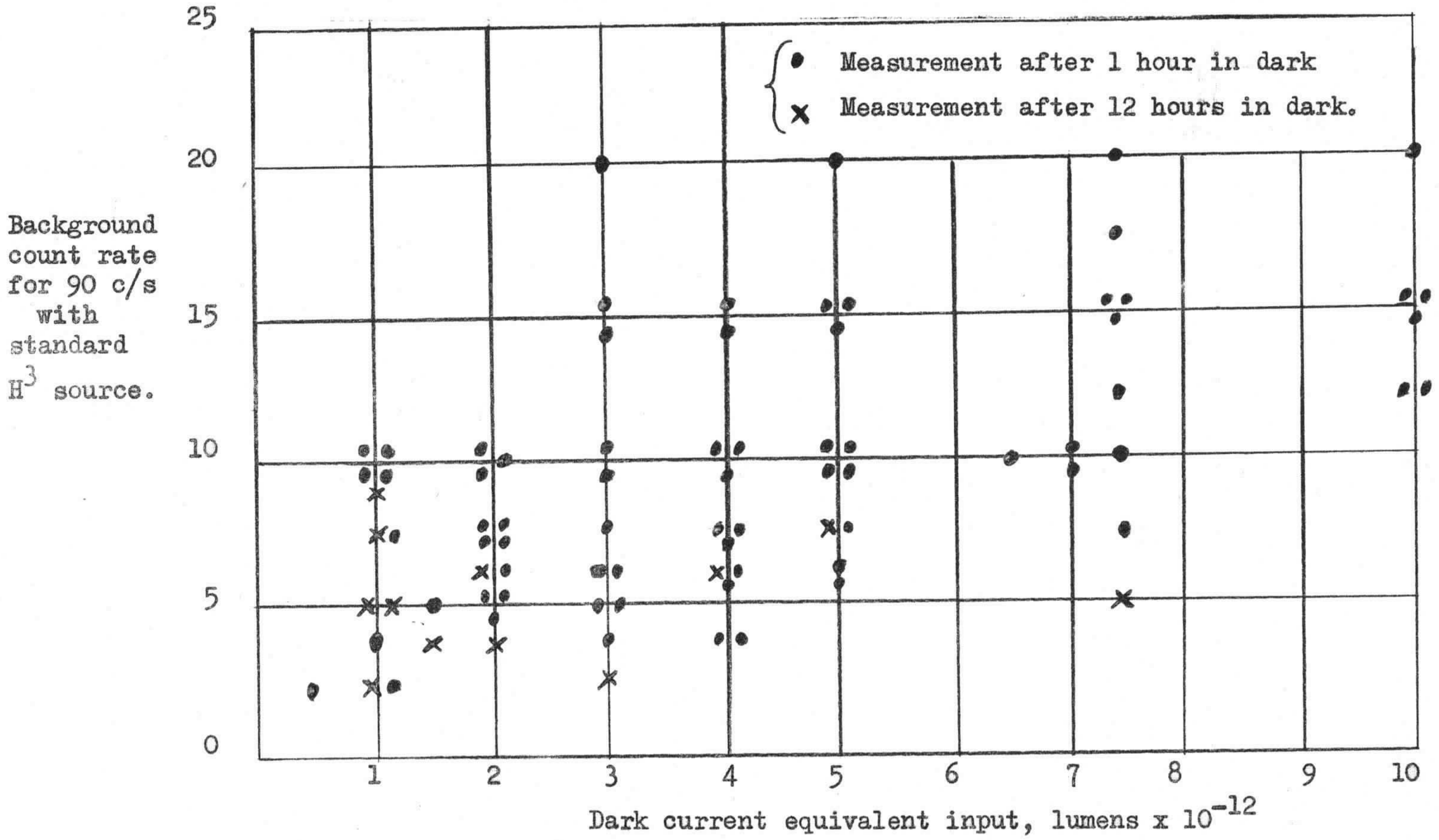
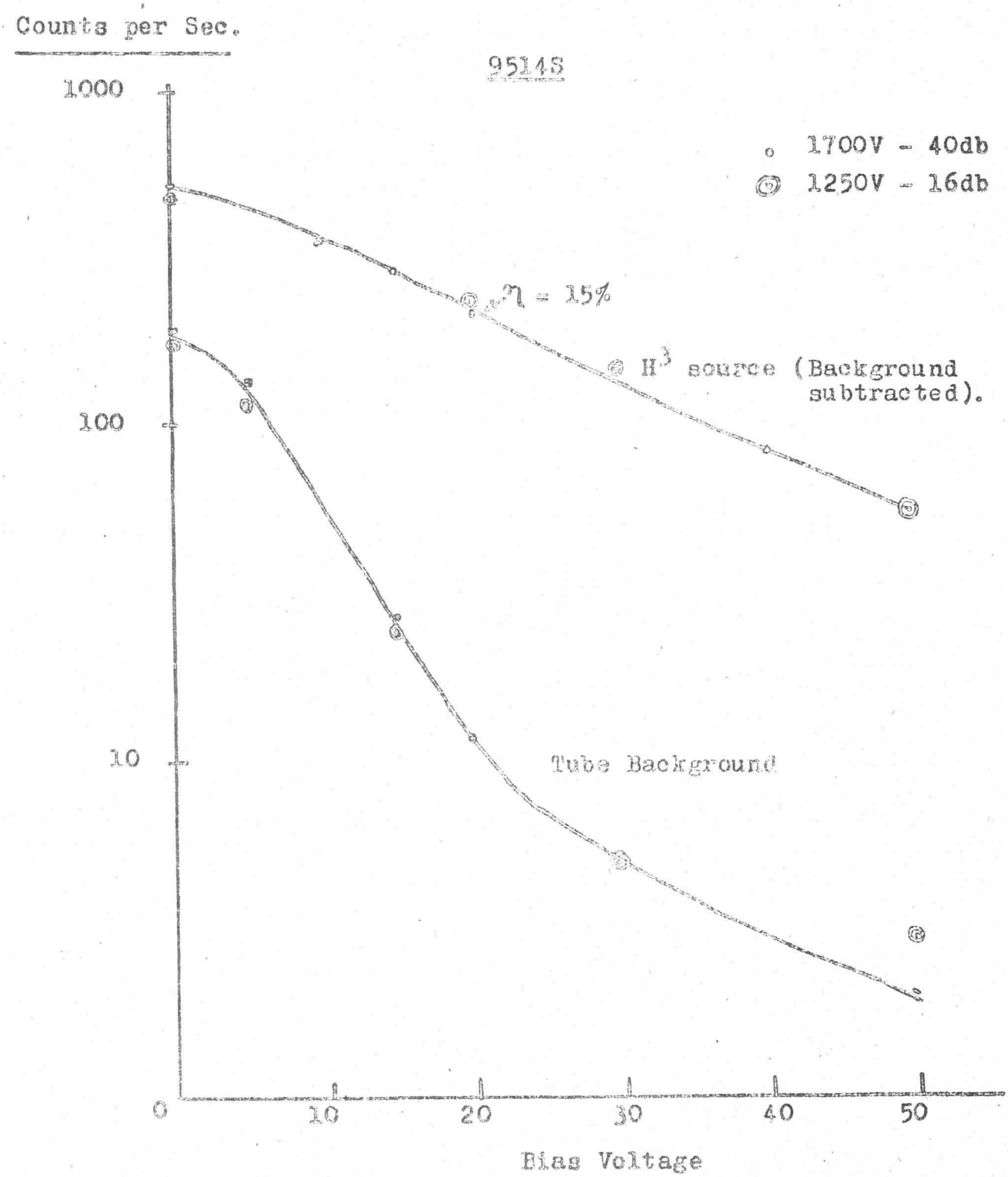


Fig. 1.

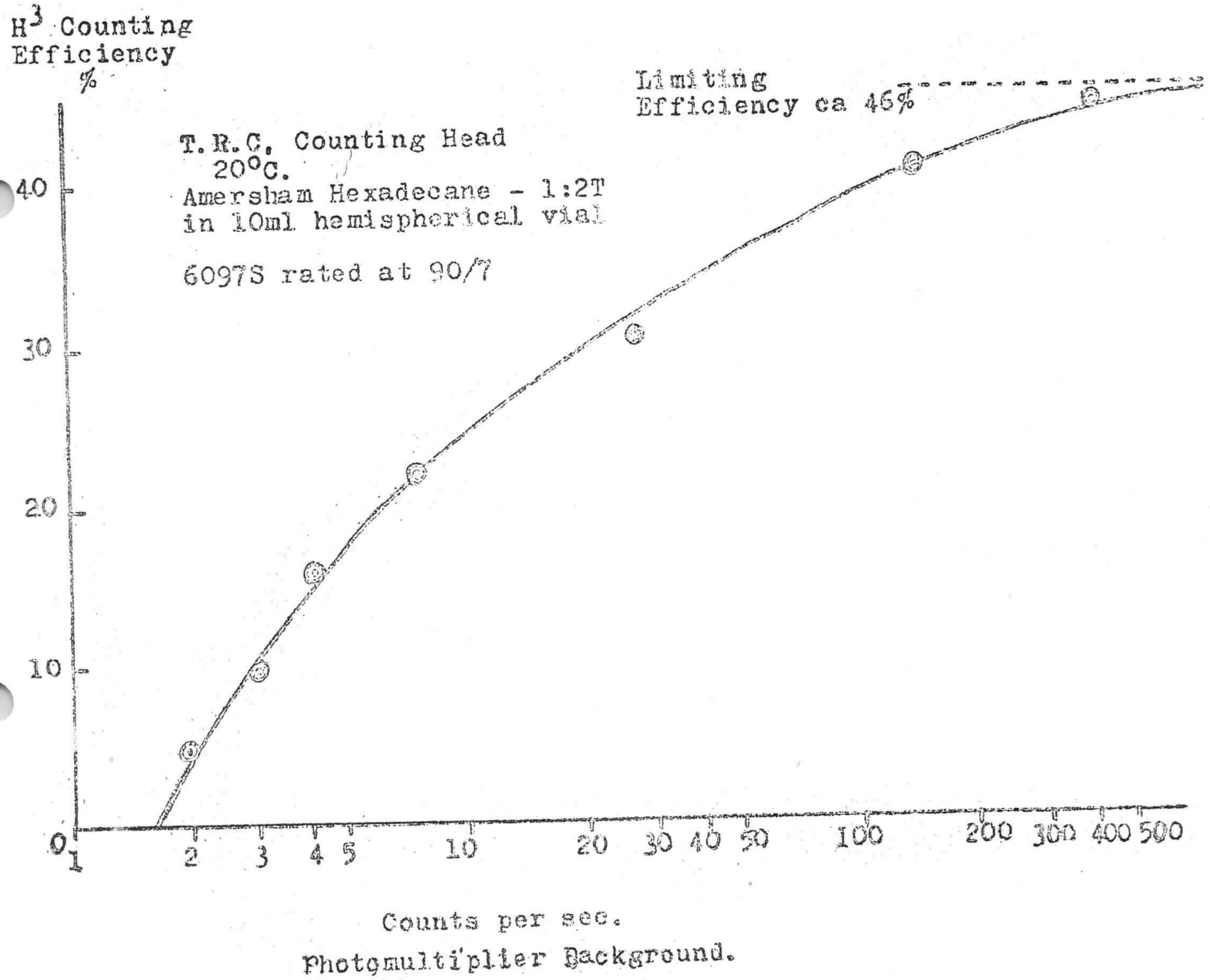
- Fig 2.



Demonstration of independence of counting properties w.r.t. voltage.

(Standard test jig used, but not standard source.)

Fig 3.



H^3 Efficiency vs. Photomultiplier tube background.

Fig 4.

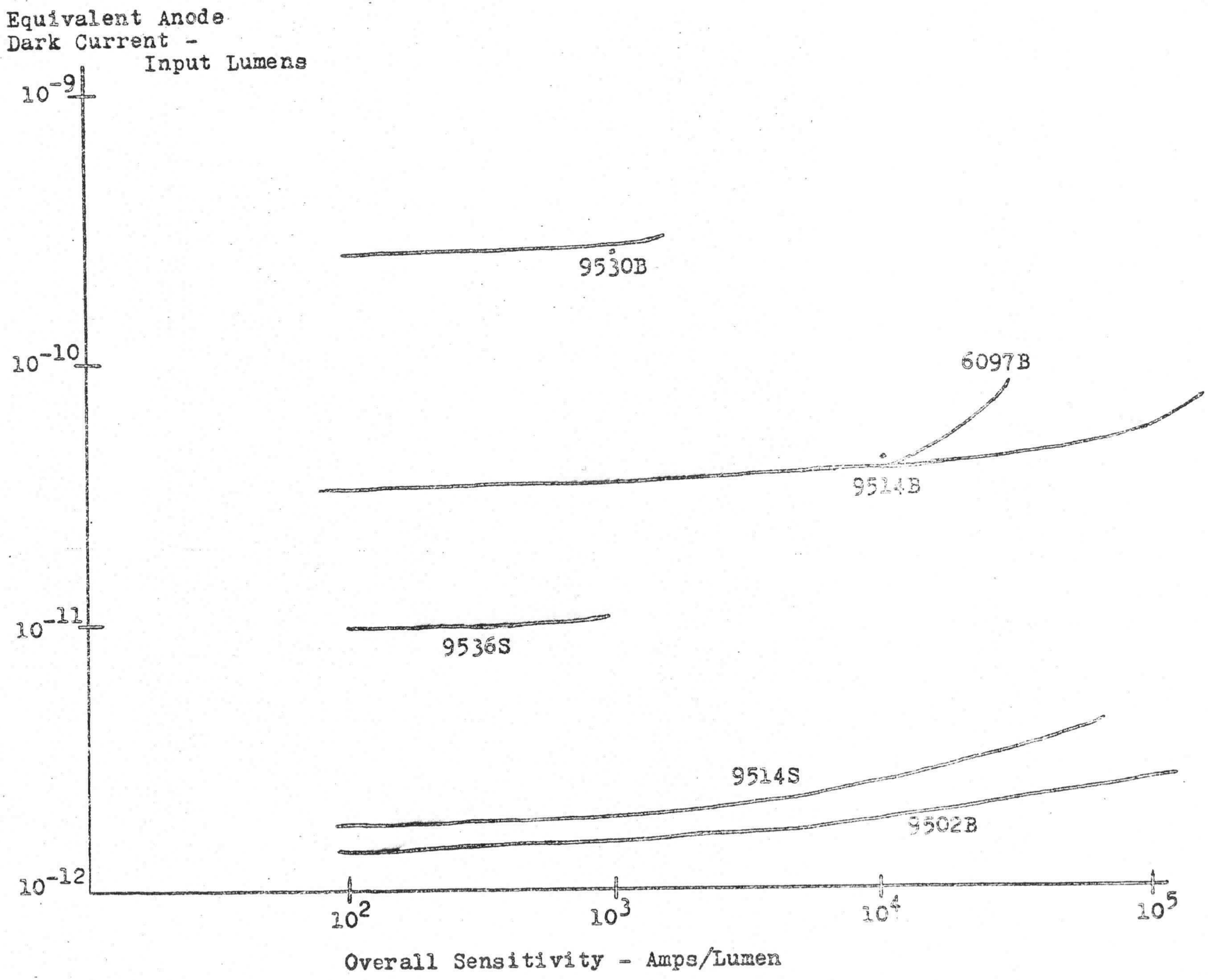
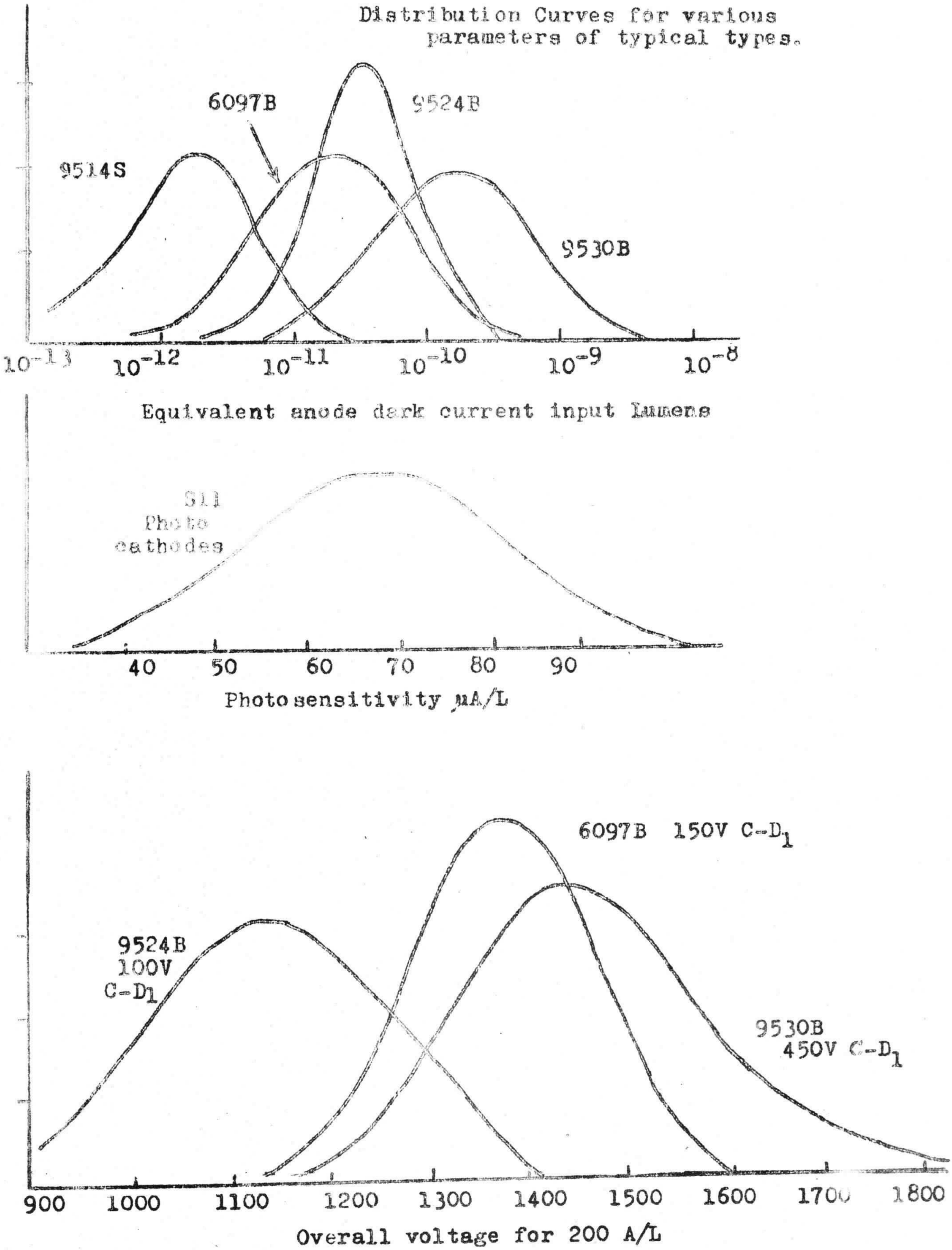

Equivalent Anode
Dark Current -
Input Lumens
10^{-9}
10^{-10}
10^{-11}
10^{-12}
9530B
6097B
9514B
9536S
9514S
9502B
10^2
10^3
10^4
10^5
Overall Sensitivity - Amps/Lumen

FIG. 5



Distribution Curves for various parameters of typical types.

6094B
F

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PHOTOMULTIPLIER TUBE TYPE 6094B

The 6094 is a high gain, 2" diameter, 1 cm cathode, 11 stage photomultiplier tube, having venetian blind type dynodes coated with CsSb secondary emitting material. The small cathode diameter coupled with the special cathode - D_1 geometry, gives a very low dark current with a cathode size adequate for spectrophotometry and similar applications.

The end window, semi-transparent photocathode in 6094B, is of CsSbO (S11 type). In 6094S it is SbCs (S type). The latter is specially processed to give minimum thermionic emission.

The tube has a glass base, type B15B, which fits a P.T.F.E. socket, available from E.M.I. Electronics Ltd.

CHARACTERISTICS (See figure on reverse of sheet).

Bulb Diameter : 51 mm. max

Cathode Diameter : 10 mm. min.

Seated Height : 94 mm. ± 3 mm.

Overall Length : 114 mm. max.

Window Material : Lime Soda (Pyrex available to special order).

ELECTRICAL

			6094B			6094S		
			Max.	Typical	Min.	Max.	Typical	Min.
Photocathode Sensitivity		µA/Lumen	-	60	40	-	35	25
Overall Sensitivity	20 A/L	Voltage V	-	1000	-	-	1150	-
	200 A/L	Voltage V	1820	1400	-	-	1480	-
		Dark current A	$5x10^{-9}$	$3x10^{-10}$	-	-	10^{-10}	-
	2000 A/L	Voltage V	-	2000	-	-	2150	-
		Dark current A	-	$3x10^{-9}$	-	-	10^{-9}	-

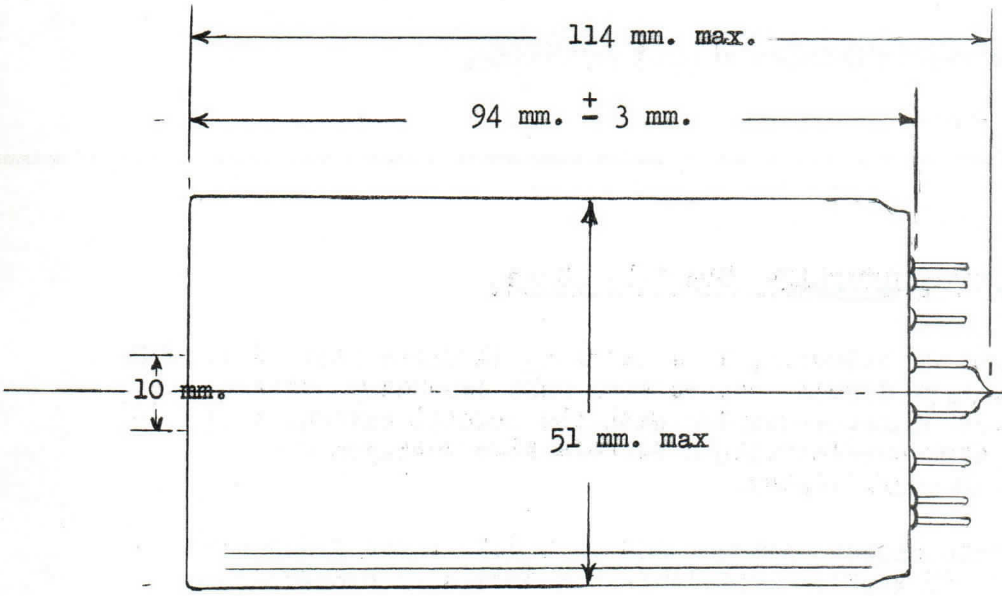
The above measurements are taken with a dynode chain giving 150V cathode - D_1 and a uniform inter-stage potential thereafter.

Anode - All dynodes :- Capacity 8 µµf

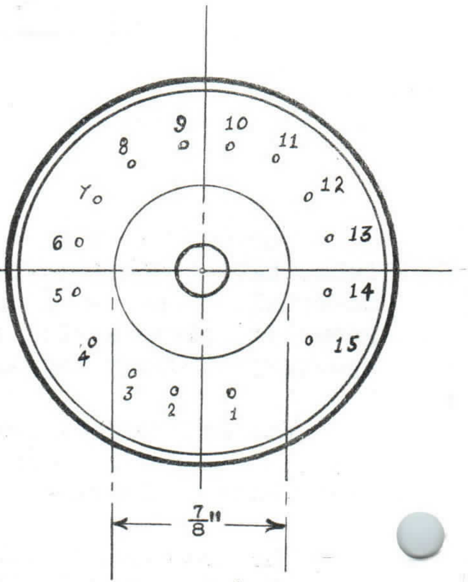
Ratings :

C-D_1	200V max.
C - Anode	2500V max.
Overall sensitivity	10,000 amps/Lumen max.
Mean Anode current	1.0 mA max.
Mean Anode dissipation	1.0 watts max.
Ambient temperature	75°C max. -80°C min.

Photomultiplier tube type 6094B



P.T.F.E. Socket
Type B15B



Fixing holes 3/16" dia.
2" between centres.

BASE CONNECTIONS

(Pins numbered clockwise from blank position, viewed from underside of tube.)

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dynode	5	7	9	11	-	A	-	10	8	6	4	2	C	1	3

A = Anode C = Cathode

NOTES.

If the tube is clamped around the body, care should be taken to avoid disturbance of the potential of the inner surface of the envelope, e.g. by connecting the clamp to cathode potential. Failure to observe this precaution may result in erratic operation, with high dark current.

It is desirable to shield the tube from the effect of strong magnetic fields, and µ-metal shields are available for this purpose.

At an overall voltage of 2000V, the rise time of an anode pulse due to a very short pulse of light will be about 7 m µsec.

For highest stability of gain under D.C. conditions, it is recommended that the anode current should not be allowed to exceed 10 µA.

The Company reserves the right to modify these designs and specifications without notice.

EC8/20.R.
10.1.61.

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EMI PHOTOMULTIPLIER TUBE TYPE 6097

The 6097 is a high gain, 2 in. diameter, 44 mm cathode, 11 stage photomultiplier tube, having venetian blind type dynodes coated with CsSb secondary emitting material. The tube is suitable for general purpose scintillation counting, and for flying spot transducer and similar applications.

The end window, semi-transparent photocathode in 6097B is of CsSbO (S11 type). In 6097S it is SbCs (S type). The latter is specially processed to give minimum thermionic emission. Specifications are available giving various combinations of the tube parameters.

The tube has a glass base, type B15B which fits a P.T.F.E. socket, available from EMI Electronics Ltd.

CHARACTERISTICS (See figure on reverse of sheet)

Bulb Diameter:	51 mm max.	Cathode Diameter:	44 mm. min.
Seated Height:	112 mm ± 3 mm	Overall Length:	132 mm max.
Window Material:	Lime Soda. (Pyrex available to special order).		

	6097B			6097S		6097F		6097G	
Sensitivity:	Max.	Avge.	Min.	Avge.	Limit	Avge.	Limit	Avge.	Limit
Photocathode µA/L		70	40	50	30*	85	50*	75	45
50 A/L overall Voltage V						1200			
Dark I_A µA						0.03	0.05^{+}		
200 A/L overall Voltage V	1750	1400	1150	1500	2000^{+}			1500^{+}	1200*
Dark I_A µA	0.010	0.005		0.001	0.01^{+}			0.02	0.05^{+}
2000 A/L overall Voltage V		2000		2100				1750	
Dark I_A µA		0.05		0.01				0.20	

* = minimum + = maximum

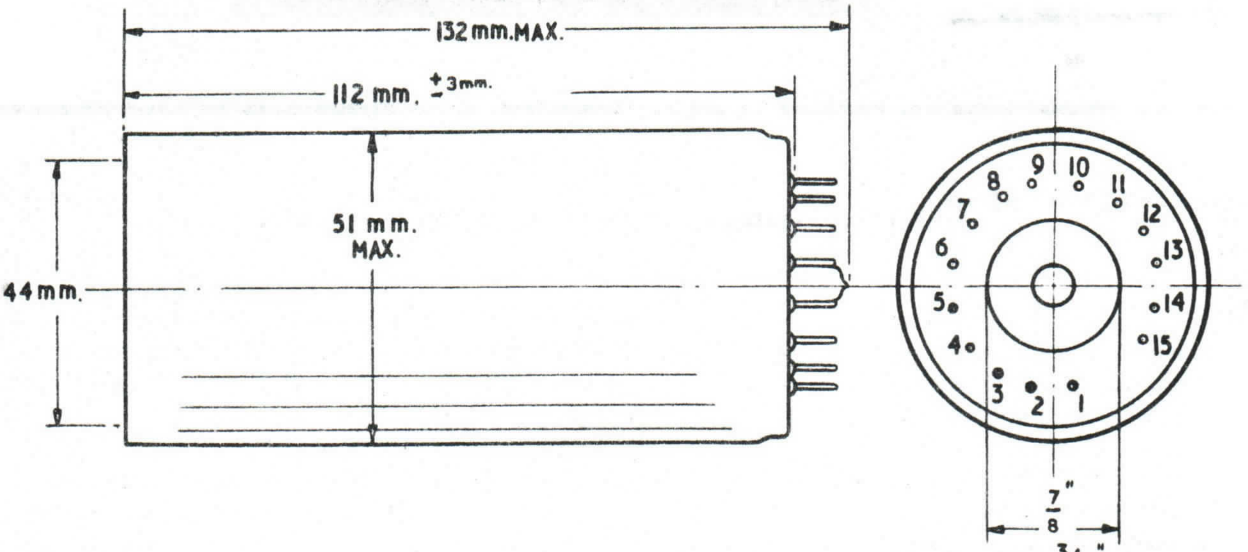
The above measurements are taken with a dynode chain giving 150V cathode - D_1 and a uniform inter-stage potential thereafter.

Anode - All dynodes : - Capacity 8 µµf.

Ratings:	C - D_1	200V max.
	C - Anode	2500V max.
	Overall sensitivity	10000 amps/lumen max.
	Mean anode current	1 mA max.
	Mean anode dissipation	1 watt max.
	Ambient temperature	75°C max. -80°C min.

EC8/P/024
MAY, 1962 (1)

DS.128/1



FIXING HOLES 3/16" DIA.
2" BETWEEN CENTRES.
P.T.F.E. SOCKET TYPE B15B

BASE CONNECTIONS: (PINS NUMBERED CLOCKWISE FROM BLANK POSITION, VIEWED FROM UNDERSIDE OF TUBE.)

PIN No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
DYNODE	5	7	9	11	∤	A	∤	10	8	6	4	2	C	1	3

A = ANODE C = CATHODE ∤ = BLANK PINS (MUST BE LEFT UNCONNECTED)

NOTES:

If the tube is clamped around the body, care should be taken to avoid disturbance of the potential of the inner surface of the envelope, e.g. by connecting the clamp to cathode potential. Failure to observe this precaution may result in erratic operation, with high dark current.

It is desirable to shield the tube from the effect of strong magnetic fields, and μ-metal shields are available for this purpose.

At an overall voltage of 2000V, the rise time of an anode pulse due to a very short pulse of light will be about 7 mμsec. For linear pulsed output currents up to over 50 mA, non linear dynode chain giving 400V per stage between D9-D10, D10-D11 and D11-Anode should be used.

For highest stability of gain under d.c. conditions, it is recommended that the anode current should not be allowed to exceed 10 μA.

EC8/P/024
MAY, 1962 (1)
DS.128/2

TD

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6225-B
F

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PHOTOMULTIPLIER TUBE TYPE 6255B

The 6255 is a high gain, quartz window, 2" diameter, 44 m.m. cathode, 13 stage photomultiplier tube, having venetian blind type dynodes coated with CsSb secondary emitting material. It is particularly suitable for general applications from 1650 Å to 6500 Å and for scintillation counting. When fitted with the E.M.I. "S" type cathode (6255S) the tube is suitable for use with liquid phosphors for the scintillation counting of ^{14}C or ^{3}H.

The end window, semi-transparent photocathode in 6255B is of CsSbO (S11 type). In 6255S it is SbCs (S type). The latter is specially processed to give minimum thermionic emission.

The tube has a glass base, type B15B, which fits a P.T.F.E. socket, available from E.M.I. Electronics Ltd.

CHARACTERISTICS

Mechanical	See figure on reverse of sheet.		
Bulb Diameter.	51.5 m.m. max.	Cathode Diameter.	44 m.m. min.
Seated Height.	121 m.m. ± 6 m.m.	Overall Length.	144 m.m. max.
Window Material.	Quartz.		

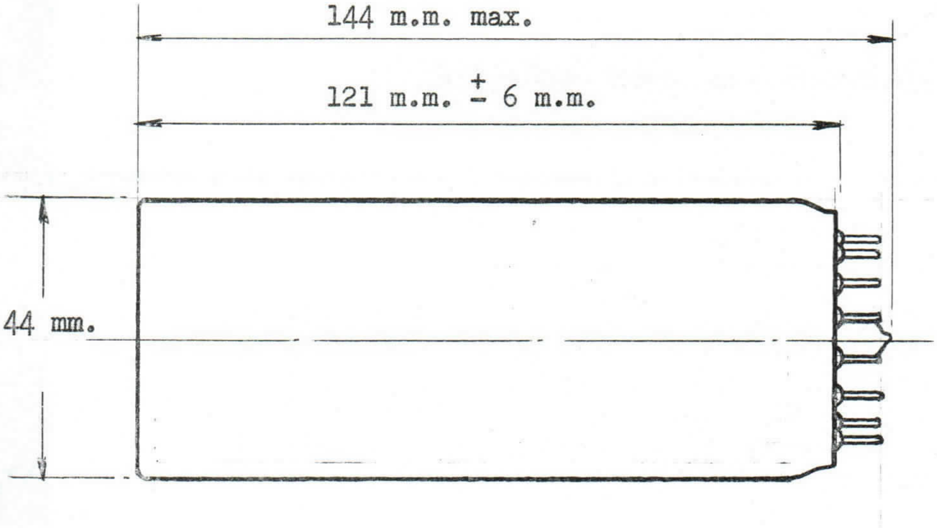
ELECTRICAL			6255B			6255S		
			Max.	Typical	Min.	Max.	Typical	Min.
Photocathode Sensitivity		μ A/L	-	55	40	-	35	25
Overall Sensitivity	200 A/L	Voltage V	-	1150	-	-	1300	-
		Dark I_A	-	0.015	-	-	0.001	-
	2,000 A/L	Voltage V	2240	1400	-	2500	1700	-
		Dark I_A	0.5	0.1	-	0.025	0.01	-
	10,000 A/L	Voltage V	-	1800	-	-	2150	-
		Dark I_A	-	2.0	-	-	0.15	-

The above measurements are taken with a dynode chain giving 150V cathode - D_1 and a uniform inter-stage potential thereafter.

Anode - All dynodes :- Capacity 8 μμf.

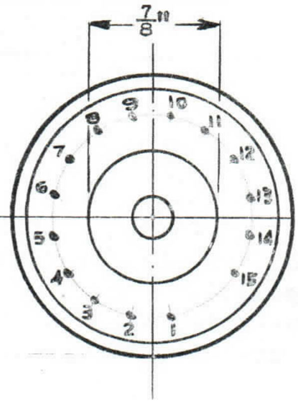
RATINGS :

C - D_1	200V max
C - Anode	2500V max.
Overall sensitivity	30,000 A/L max.
Mean Anode current	1.0 mA max.
Mean Anode dissipation	1.0 watts max.
Ambient temperature	75°C max. -80°C min.



P.T.F.E. Socket type B15B.

Fixing holes 3/16" radius
between centres.



BASE CONNECTIONS : (Pins numbered clockwise from blank position, viewed from underside of tube.

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dynode	5	7	9	11	13	A	12	10	8	6	4	2	C	1	3

A = Anode C = Cathode.

NOTES :

If the tube is clamped around the body, care should be taken to avoid disturbance of the potential of the inner surface of the envelope, e.g. by connecting the clamp to cathode potential. Failure to observe this precaution may result in erratic operation, with high dark current.

It is desirable to shield the tube from the effect of strong magnetic fields, and μ-metal shields are available for this purpose.

At an overall voltage of 2000V, the rise time of an anode pulse due to a very short pulse of light will be about 7 mμS.

For highest stability of gain under D.C. conditions, it is recommended that the anode current should not be allowed to exceed 10 μA.

EC8/29.R.
26.1.61.

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PHOTOMULTIPLIER TUBE TYPE 6256B.

The 6256 is a high gain, quartz window, 2" diameter, 1 cm cathode, 13 stage Photomultiplier tube, having venetian blind type dynodes coated with CsSb secondary emitting material. The small cathode diameter coupled with the special cathode - D_1 geometry, gives a very low dark current with a cathode size adequate for spectrophotometry and similar applications from 1650 ÅU to 6500 ÅU.

The end window, semi-transparent photocathode in 6256B is of CsSbO (S13 type). In 6256S it is SbCs (S type). The latter is specially processed to give minimum thermionic emission.

The tube has a glass base, type B15B, which fits a P.T.F.E. socket, available from E.M.I. Electronics Ltd.

CHARACTERISTICS (See figure on reverse of sheet)

Bulb diameter : 51.5 mm. max. **Cathode diameter** : 10 mm. min.

Seated height : 108 mm ± 6 mm. **Overall length** : 130 mm. max.

Window material : Fused quartz.

ELECTRICAL			6256B			6256S		
			Max.	Typical	Min.	Max.	Typical	Min.
Photocathode sensitivity		µA/L	–	50	40	–	35	30
Overall sensitivity	20 A/L	Voltage V	–	900	–	–	950	–
		Dark I_A µA	–	–	–	–	–	–
	200 A/L	Voltage V	–	1200	–	–	1300	–
		Dark I_A µA	–	2.5×10^{-9}	–	–	3×10^{-10}	–
	2,000 A/L	Voltage V	2240	1500	–	2500	1700	–
		Dark I_A µA	5×10^{-8}	2×10^{-8}	–	10^{-8}	2.5×10^{-9}	–
	10,000 A/L	Voltage V	–	1900	–	–	2150	–
		Dark I_A µA	–	2×10^{-7}	–	–	1.5×10^{-8}	–

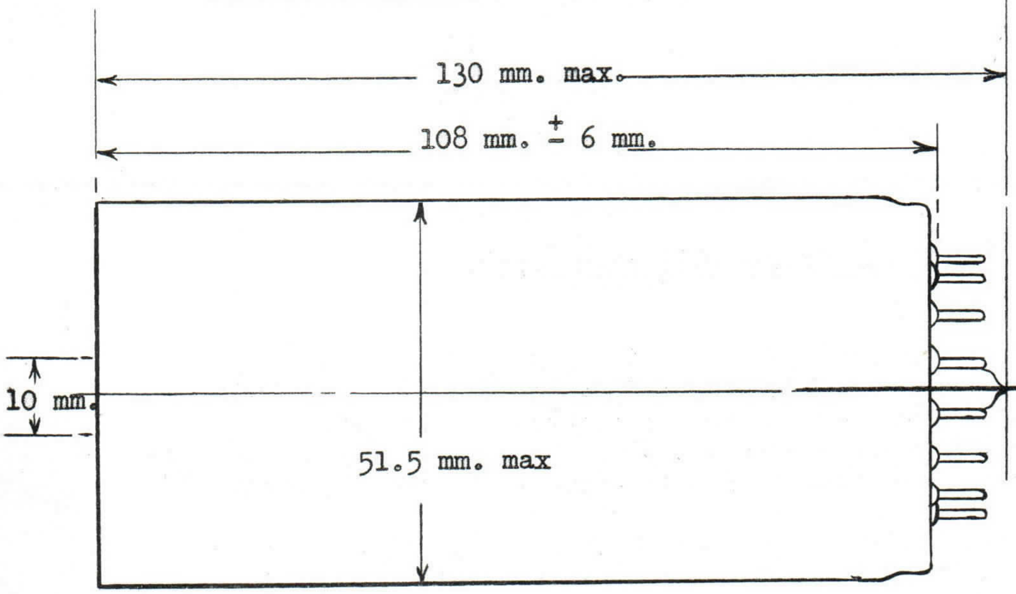
The above measurements are taken with a dynode chain giving 150 V cathode - D_1 and a uniform inter-stage potential thereafter.

Anode - all dynodes : - Capacity 8 µµf

Ratings :

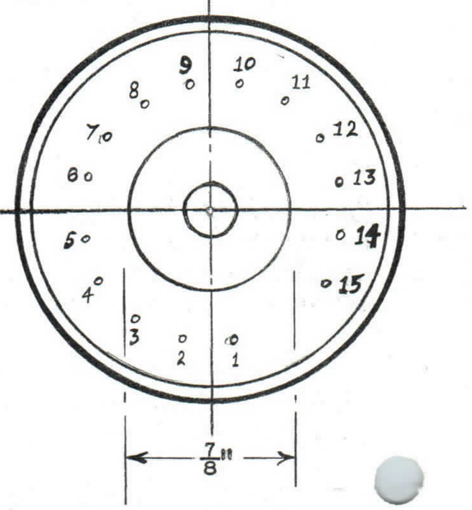
C - D_1 : 200 V max.
C - Anode : 2500 V max.
Overall sensitivity : 30,000 A/L max.
Mean anode current : 1.0 mA max.
Mean anode dissipation : 1.0 watts max.
Ambient temperature : 75°C max. -80°C min.

Photomultiplier tube type 6256B



P.T.F.E. Socket type B15B.

Fixing holes 3/16" radius
2" between centres.



BASE CONNECTIONS (Pins numbered clockwise from blank position, viewed from underside of tube.)

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dynode	5	7	9	11	13	A	12	10	8	6	4	2	C	1	3

A = Anode C = Cathode

NOTES

If the tube is clamped around the body, care should be taken to avoid disturbance of the potential of the inner surface of the envelope, e.g. by connecting the clamp to cathode potential. Failure to observe this precaution may result in erratic operation, with high dark current.

It is desirable to shield the tube from the effect of strong magnetic fields and mu-metal shields are available for this purpose.

At an overall voltage of 2000 V, the rise time of an anode pulse due to a very short pulse of light will be about 7 mμsec.

For highest stability of gain under D.C. conditions, it is recommended that the anode current should not be allowed to exceed 10 μA.

EC8/53
11.1.61.

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PHOTOMULTIPLIER TUBE TYPE 9502B

The 9502 is a high gain, 2" diameter, 1 cm cathode, 13 stage photomultiplier tube, having venetian blind type dynodes coated with CsSb secondary emitting material. The small cathode diameter coupled with the special cathode - D_1 geometry, gives a very low dark current with a cathode size adequate for spectrophotometry and similar applications.

The end window, semi-transparent photocathode in 9502B, is of CsSbO (S11 type). In 9502S it is SbCs (S type). The latter is specially processed to give minimum thermionic emission.

The tube has a glass base, type B15B, which fits a P.T.F.E. socket, available from E.M.I. Electronics Ltd.

CHARACTERISTICS

Mechanical. See figure on reverse of sheet.

Bulb Diameter.	51 m.m. max.	Cathode Diameter.	10 m.m. min.
Seated Height	108 m.m. ± 3 m.m.	Overall Length.	128 m.m. max.

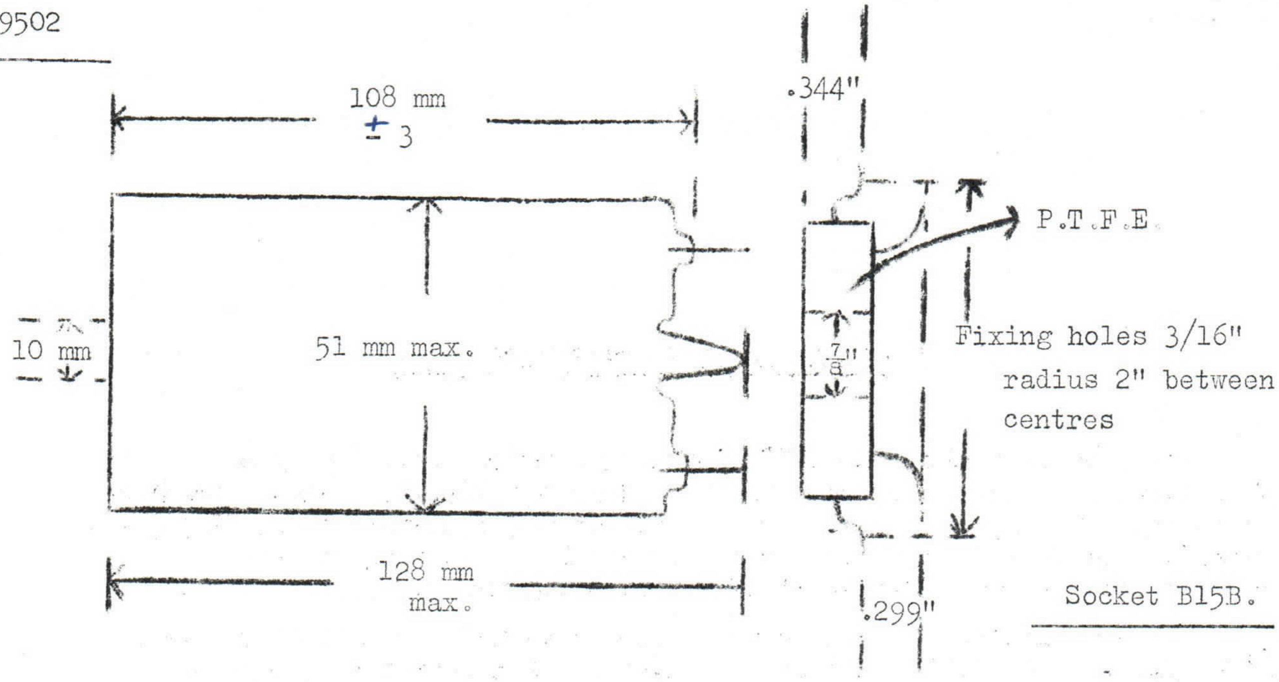
Window Material. Lime Soda (Pyrex available to special order).

Electrical.		9502B			9502S		
		Max.	Typical	Min.	Max.	Typical	Min.
Photocathode Sensitivity	µA/Lumen	-	50	30	-	30	-
Overall Sensitivity 20 amps/Lumen	Voltage V	-	900	-	-	950	-
	Dark current A	-	-	-	-	-	-
Overall Sensitivity 200 amps/Lumen	Voltage V	-	1200	-	-	1300	-
	Dark current A	-	2.5×10^{-9}	-	-	3×10^{-10}	-
Overall Sensitivity 2000 amps/Lumen	Voltage V	2240	1500	-	2500	1700	-
	Dark current A	10^{-7}	2×10^{-8}	-	10^{-8}	2.5×10^{-9}	-
Overall Sensitivity 10,000 amps/Lumen	Voltage V	-	1900	-	-	2150	-
	Dark current A	-	2×10^{-7}	-	-	1.5×10^{-8}	-

The above measurements are taken with a dynode chain giving 150V cathode $-D_1$ and a uniform inter-stage potential thereafter.

Anode - All dynodes :- Capacity 8µµf.

Ratings
$C-D_1$ 200V max. C - Anode 2500V max.
Overall sensitivity 30,000 amps/Lumen max.
Mean Anode current 1.0 mA max.
Mean Anode dissipation 1.0 watts max.
Ambient temperature 75°C max. -80°C min.



Base Connections (Pins numbered clockwise from blank position, viewed from underside of tube.)

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dynode	5	7	9	11	13	A	12	10	8	6	4	2	C	1	3

A = Anode C = Cathode

NOTES :

If the tube is clamped around the body, care should be taken to avoid disturbance of the potential of the inner surface of the envelope, e.g. by connecting the clamp to cathode potential. Failure to observe this precaution may result in erratic operation, with high dark current.

It is desirable to shield the tube from the effect of strong magnetic fields, and μ-metal shields are available for this purpose.

At an overall voltage of 2000V, the rise time of an anode pulse due to a very short pulse of light will be about 7 m μsec.

For highest stability of gain under D.C. conditions, it is recommended that the anode current should not be allowed to exceed 10 μA.

EMI Electronics Ltd Valve Division
HAYES MIDDLESEX ENGLAND (*Controlled by Electric and Musical Industries Ltd*)
Telephone: *Southall 2468* Cables: *Emidata, London.* Telex *London 22417*

Printed in England by E.M.I. Ltd.

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VALVE DIVISION

PHOTOMULTIPLIER TUBES TYPE 9514B and 9514S.

The 9514 is a high gain, 2" diameter, 44 m.m. cathode, 13 stage photomultiplier tube, having venetian blind type dynodes coated with CsSb secondary emitting material. This tube is particularly suitable for general applications including scintillation counting. When fitted with the E.M.I. "S" cathode the tube is suitable for use with liquid phosphors for the scintillation counting of ^{14}C or ^{3}H.

The end window, semi-transparent photocathode in 9514B, is of CsSbO (S11 type). In 9514S it is SbCs (S type). The latter is specially processed to give minimum thermionic emission.

The tube has a glass base, type B15B, which fits a P.T.F.E. socket, available from E.M.I. Electronics Ltd.

CHARACTERISTICS.

Mechanical. See figure on reverse of sheet.

Bulb Diameter. 51 m.m. max. Cathode Diameter. 44 m.m. min.

Seated Height. 121 m.m. ± 3 m.m. Overall Length. 141 m.m. max.

Window Material. Lime Soda. (Pyrex available to special order).

Electrical.

		9514B			9514S		
		Max.	Typical	Min.	Max.	Typical	Min.
Photocathode Sensitivity.	μA/Lumen	-	50	30	-	30	20
Overall Sensitivity 20 amps/Lumen	Voltage V	-	-	-	-	-	-
	Dark current A	-	-	-	-	-	-
Overall Sensitivity 200 amps/Lumen	Voltage V	-	1150	-	-	1300	-
	Dark current A	-	2.5×10^{-8}	-	-	3×10^{-9}	-
Overall Sensitivity 2,000 amps/Lumen	Voltage V	2240	1400	-	2500	1700	-
	Dark current A	10^{-6}	2×10^{-7}	-	10^{-7}	2×10^{-8}	-
Overall Sensitivity 10,000 amps/Lumen	Voltage V	-	1800	-	-	2150	-
	Dark current A	-	2×10^{-6}	-	-	1.5×10^{-7}	-

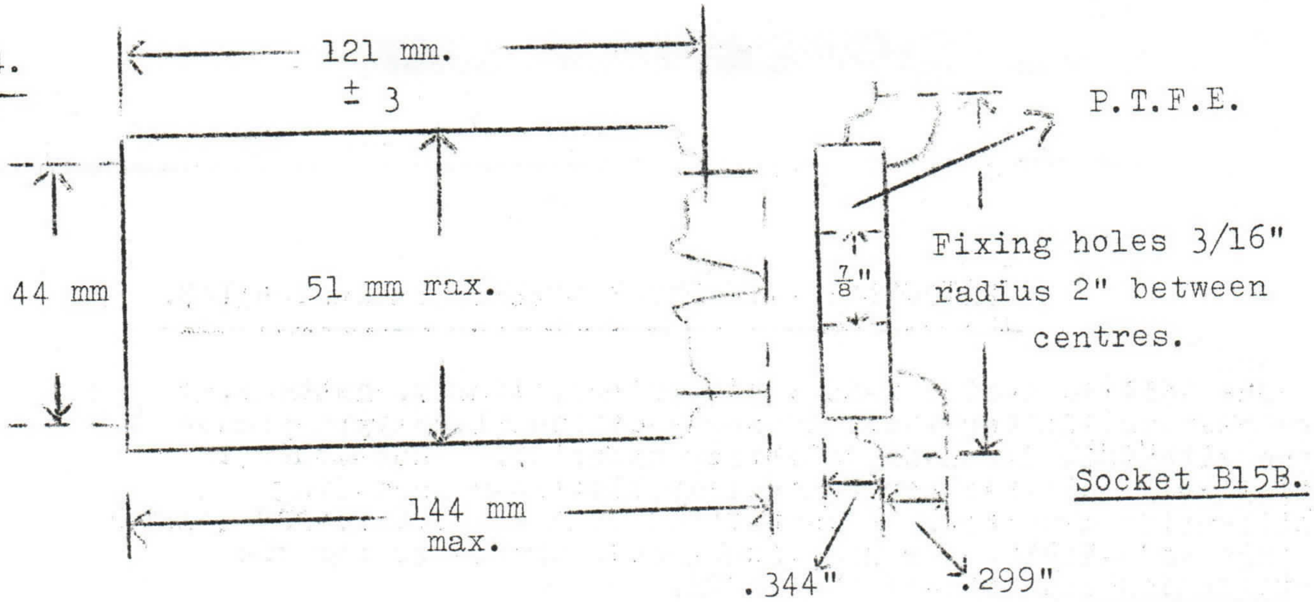
The above measurements are taken with a dynode chain giving 150V cathode $-D_1$ and a uniform inter-stage potential thereafter.

Anode - All dynodes :- Capacity 8 pf.

Ratings $C-D_1$ 200V max. C - Anode 2500V max.

Overall sensitivity	30,000 amps/Lumen max.
Mean Anode current	1.0 mA max.
Mean Anode dissipation	1.0 watts max.
Ambient temperature	75°C max. - 80°C min.

9514.



BASE CONNECTIONS (Pins numbered clockwise from blank position, viewed from underside of tube.)

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dynode	5	7	9	11	13	A	12	10	8	6	4	2	C	1	3

A = Anode C = Cathode.

NOTES :

If the tube is clamped around the body, care should be taken to avoid disturbance of the potential of the inner surface of the envelope, e.g. by connecting the clamp to cathode potential. Failure to observe this precaution may result in erratic operation, with high dark current.

It is desirable to shield the tube from the effect of strong magnetic fields, and μ-metal shields are available for this purpose.

At an overall voltage of 2000V, the rise time of an anode pulse due to a very short pulse of light will be about 8 mμsec.

For highest stability of gain under D.C. conditions, it is recommended that the anode current should not be allowed to exceed 10μA.

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PHOTOMULTIPLIER TUBE TYPE 9524B

The 9524B is a high-gain small-diameter photomultiplier, (1⅛ inches max.) having 11 dynodes of the box and grid type which are coated with CsSb secondary emitting material.

The end window semi-transparent photocathode is of the Cs-Sb-O type, with maximum sensitivity in the blue region of the spectrum, an average tube having a peak quantum efficiency of ca 17% at 4200AU.

The high gain and small diameter of the tube make it particularly suitable for use in portable scintillation detectors, while the low dark current suggests many uses in spectrophotometry.

The tube has a glass base, type B14B, which fits a PTFE socket of small outside diameter, so that the whole assembly may be fitted into a tube of 1⅛ inch inside diameter.

CHARACTERISTICS

Mechanical (see figure on reverse of sheet)

Bulb diameter 1.125 in max. (28.6 mm)
Seated height 4.41 in. (112 ± 3 mm)

Cathode diameter - 0.937 in. min
Window material - Lime soda

Electrical

		Max.	Typical	Min.
Photocathode sensitivity	μA/L		60	40
	Voltage V	1000	750	
Overall sensitivity				
20 Amps/lumen	Dark current μA	0.01	0.002	
200 Amps/lumen	Voltage V	1350	1100	
	Dark current μA	0.02	0.005	
2000 Amps/lumen	Voltage V	2000	1600	
	Dark current μA	1.0	0.2	

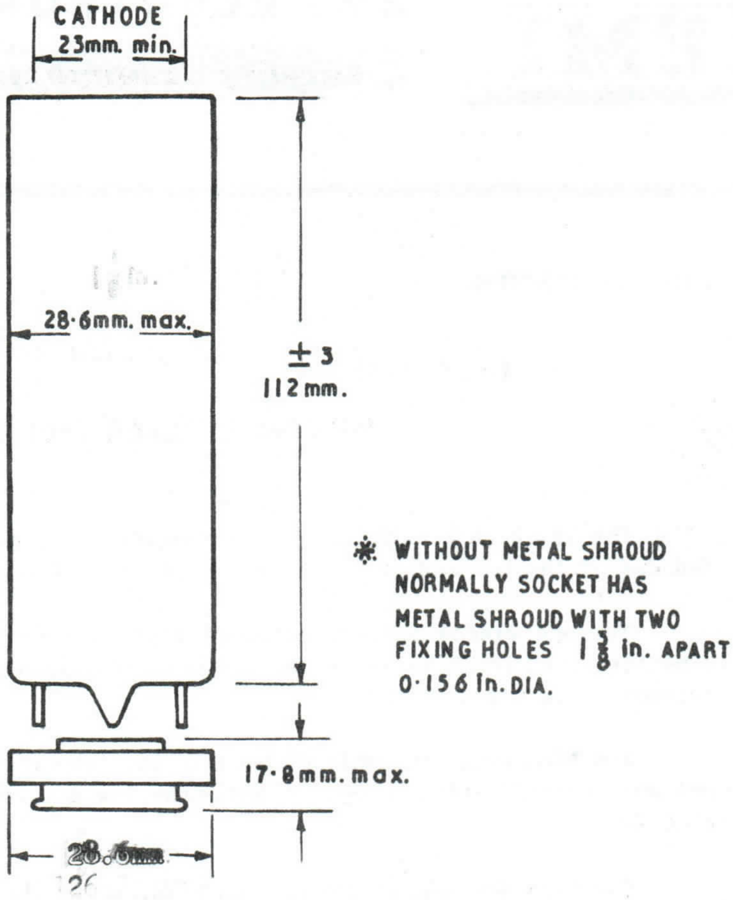
Measurements made with C-D1 100V, dynode chain with voltage D9-D10, D10-D11 and D11-Anode twice that between D1-D2. D2-D3, etc.

Ratings

C-D1 150V max. V-Anode 2000V max.
Overall sensitivity 3000 Amps/lumen

Mean anode current - 1mA max. Mean anode dissipation - 1.0W
Ambient temperature 75 °C max. -80 °C min.

DIMENSIONS FOR
9524



BASE CONNECTIONS

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Electrode	-	3	5	7	9	11	A	10	8	6	4	2	C	1

A - Anode C = Cathode

This Basic Tube is available in the following forms:-

9524B	S11 Cathode for general use
9524S	Low Thermionic Emission Cathode, for low energy scintillation counting
9526B	Quartz Window S.13 Cathode, [illegible]
9528B	Glass Window S.10 Cathode
9529B	Quartz Window S.10 Cathode, [illegible]

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TD/1139/25M/1261/ LTD 40040

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PHOTOMULTIPLIER TYPE 9526B

The 9526B is a high gain, small diameter, quartz window, photomultiplier, ($1\frac{1}{8}$" max.) having 11 dynodes of the box and grid type which are coated with CsSb secondary emitting material.

The quartz end window semi-transparent photocathode is of the Cs-Sb-O type, (S13), with maximum sensitivity in the blue region of the spectrum, an average tube having a peak quantum efficiency of ca 12% at 4200 AU. Sensitivity drops to zero around 1650°AU. at the quartz cut-off.

The high gain and small diameter of the tube make it particularly suitable for use in portable instruments, while the low dark current and ultra-violet sensitivity suggests many uses in spectrophotometry.

The tube has a glass base, type B14B, which fits a PTFE socket of small outside diameter.

CHARACTERISTICS

MECHANICAL (See figure on reverse of sheet).

Bulb diameter	1.187" max.	Cathode diameter	15/16"(23mm)
Seated height	(112 ± 3mm)	Window material	Fused quartz.

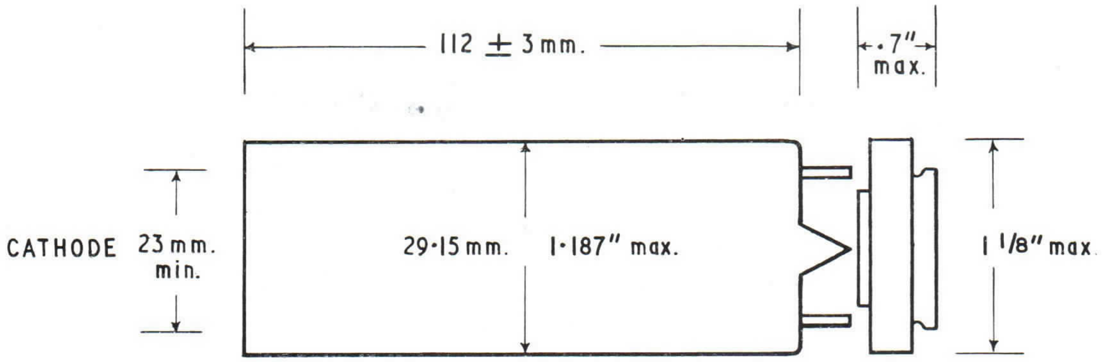
ELECTRICAL		Max.	Typical	Min.
Photocathode sensitivity	µA/L	-	40	30
	Voltage V	1000	750	-
Overall sensitivity				
20 Amps/lumen	Dark current µA.	0.01	0.002	-
200 Amps/lumen	Voltage V	1400	1100	-
	Dark current µA.	0.05	0.01	-
2000 Amps/lumen	Voltage V	2000	1600	-
	Dark current µA.	1.0	0.2	-

Measurements made with C-D1 100V, dynode chain with voltage D9-D10, D10-D11, and D11-Anode twice that between D1-D2, D2-D3, etc.

Ratings C-D1 150V max. C-Anode 2000V max.
Overall sensitivity 3000A/L max.

Mean anode current 1 mA max. Mean anode dissipation 1.0W

Ambient temperature 75°C max, -80°C min.



Not to Scale.

* Without metal shroud

DIMENSIONS FOR 9524

Normally socket has metal shroud with two fixing holes $1\frac{3}{8}$" apart .156" dia.

BASE CONNECTIONS

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Electrode	-	3	5	7	9	11	A	10	8	6	4	2	C	1

A = Anode

C = Cathode

This basic tube is available in the following forms :-

9524B	S11 Cathode for general use.
9524S	Low thermionic emission cathode, for low energy scintillation counting.
9526B	Quartz window S11 Cathode, 30.5 mm. neck dia.
9528B	Glass window S10 Cathode.
9529B	Quartz window S10 Cathode, 30.5 mm. neck dia.

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EMI PHOTOMULTIPLIER TUBE TYPE 9530B

The 9530B is a 127 mm (5 in) diameter flat face end window photomultiplier tube having 11 venetian-blind type dynodes with highly stable CsSb secondary emission surfaces.

The cathode is of the Sb-Cs-O (S11) type having maximum sensitivity in the blue region of the spectrum, the peak quantum efficiency at 4200Å being typically 12½ to 15%. Optimum collection of electrons from the cathode into the large area first dynode is accomplished by adjustment of the potential applied to a focusing electrode. This efficient collection, coupled with the high photosensitivity and high D1 gain, render the tube particularly useful for many scintillation counter applications, including gamma ray spectroscopy with a 110 mm diameter NaI-Tl crystal. The high gain and high output current decrease the need for following amplification.

The tube is fitted with a 15 pin glass base, type B15B, and may be supplied complete with a PTFE socket if required.

CHARACTERISTICS

Mechanical (See fig. overleaf)

Bulb diameter:	130 mm max.	Cathode diameter:	111 mm min.
Neck diameter:	54 mm max.	Seated height:	170 ± 3 mm

Electrical

				Max.	Typical	Min.
Photocathode sensitivity			μA/lm		50	30
Overall sensitivity	100 A/lm	*Voltage	V	1800		
		Dark current	μA	0.2		
	200 A/lm	*Voltage	V	2100	1500	
		Dark current	μA	1.0	0.25	
	200 A/lm	+Voltage	V		2600	
		Dark current	μA		2.0	

* C to D1 voltage 450V, Focus Electrode 100V -ve to D1, uniform dynode chain.

\+ C to D1 voltage 450V, Focus Electrode 100V -ve to D1, uniform dynode chain to D9, 400V per stage D9 to D10, D10 to D11, D11 to Anode. 50 mA peak linear output.

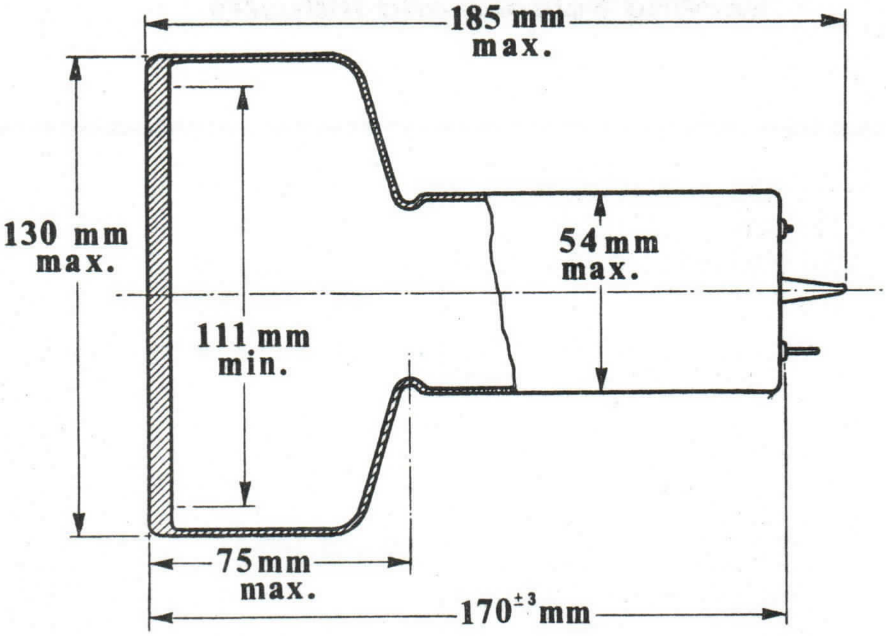
Ratings C to D1 500V max. C to Anode 2800V max.

Mean anode current 1 mA max. Mean anode dissipation 1.5 W max.

Ambient temperature 75° C max. -80° C min.

P062/1b
DS. 36/1

EMI PHOTOMULTIPLIER TUBE TYPE 9530B



BASE CONNECTIONS:-

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Electrode	-	D1	D3	D5	D7	D9	D11	A	D10	D8	D6	D4	D2	F	C

A = Anode   C = Cathode   D = Dynode   F = Focus

This Basic Photomultiplier is available in the following Types.

9530B	S11 Cathode for general scintillation counting
* 9530IR	S1 Cathode
9583B	Capped version Diheptal base fitting B14A socket. Seated height 210 mm max.

* This tube is made to special order only.

P062/2b
DS. 36/2

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PHOTOMULTIPLIER TUBE TYPE 9531B

The 9531B is a 3½ inch diameter flat face end window multiplier phototube having 11 venetian-blind type dynodes with highly stable CsSb secondary emission surfaces.

The semi-transparent photocathode is of the Cs-Sb-O (S11) type, with maximum sensitivity in the blue region of the spectrum, an average tube having a quantum efficiency of ca 15% at 4200 ÅU. Optimum collection of electrons from the cathode into the large area first dynode is accomplished by adjustment of the potential applied to a focussing electrode.

A high average photosensitivity coupled with efficient electron collection and a high value of D1 gain combine to render the tube particularly useful for scintillation gamma-ray spectroscopy with a 3 inch NaI-Tl crystal, with which typically a resolution to Cs^{137} of 8% is achieved.

The ability of the design to provide a high gain with a peak output linear to 50 mA, and a rise time of 7 millimicroseconds makes it suitable for coincidence work.

The tube is fitted with a 15 pin glass base, type B15B and a PTFE socket is available from EMI Electronics Ltd.

CHARACTERISTICS

Mechanical (See figure on reverse of sheet).

Bulb diameter:	91 mm. max.	Neck diameter:	54 mm. max.
Overall Length:	175 mm. max.	Seated height:	155 mm. ± 3 mm.
Cathode diameter:	75 mm. min.	Window Material:	Pyrex.

Electrical

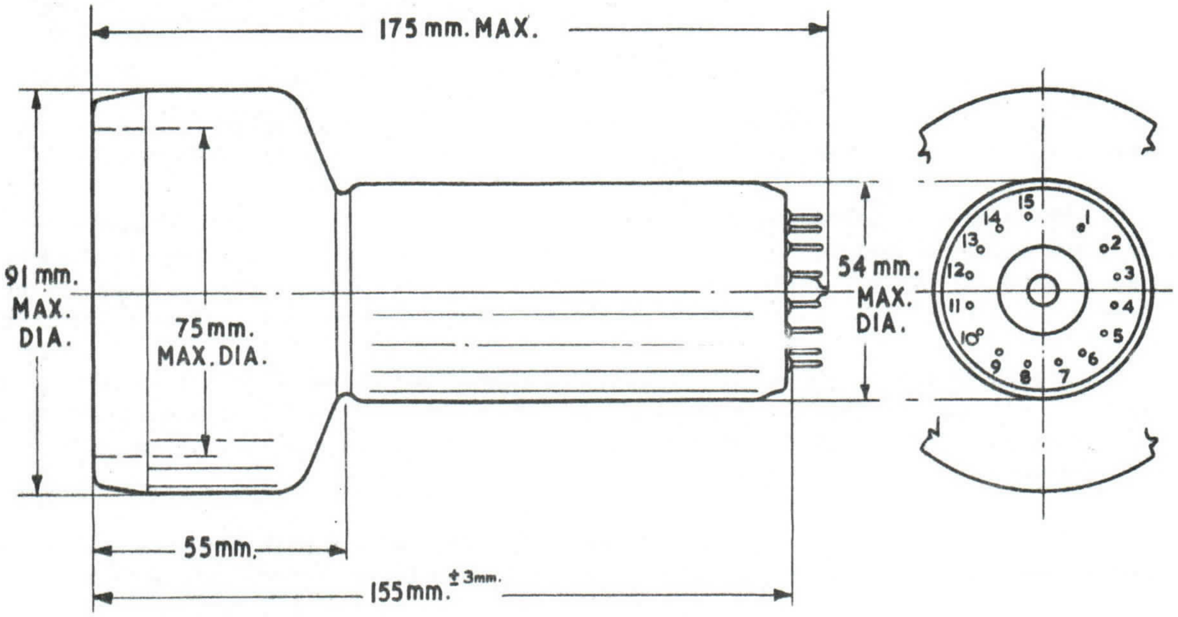
			Max.	Typical	Min.
Photocathode sensitivity		μA/L		70	40
Overall sensitivity 50 Amps/lumen	) Voltage*	V		1200	
	) Dark current	μA		0.025	
200 Amps/lumen	) Voltage*	V	1900	1400	
	) Dark current	μA	0.25	0.10	
2000 Amps/lumen	) Voltage ɸ	V		2500	
	) Dark current	μA		2	

* 300V cathode-D1, then uniform dynode chain. Focus electrode adjusted. (ca 100V negative to D1).

ɸ 300V cathode to D1, then uniform chain to D8, then 400V per stage D8-D9, D9-D10, and D10-Anode, giving 50 mA linear peak output. Focus electrode adjusted.

Ratings (Max.) C-D1 350V Max. C-Anode 2800V Max.
Mean anode current 1mA. Mean anode dissipation 1.5W Max.
Ambient temperature 75° Max. - 80°C Min.

PHOTOMULTIPLIER
TUBE TYPE
9531B



BASE CONNECTIONS: (PINS NUMBERED CLOCKWISE FROM BLANK POSITION, VIEWED FROM UNDERSIDE OF TUBE)

PIN No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ELECTRODE		D1	D3	D5	D7	D9	D11	A	D10	D8	D6	D4	D2	F	C

A = ANODE F = FOCUS ELECTRODE C = CATHODE

NOTES

If the tube is clamped around the body, care should be taken to avoid disturbance of the potential of the inner surface of the envelope, e.g. by connecting the clamp to cathode potential. Failure to observe this precaution may result in erratic operation, with high dark current.

It is desirable to shield the tube from the effect of strong magnetic fields, and μ-metal shields are available for this purpose.

For highest stability of gain under d.c. conditions, it is recommended that the anode current should not be allowed to exceed 10 μA.

TD

EC8/10-R
31.10.60.

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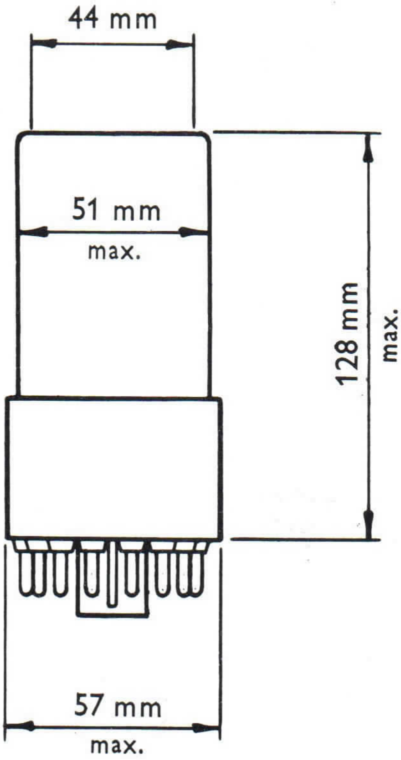
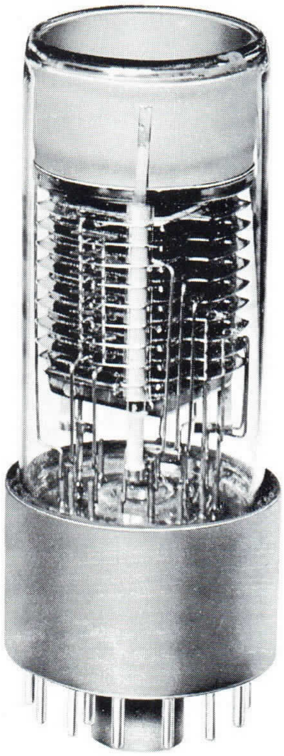
VALVE DIVISION

Photomultiplier Type ***9536B***





DESCRIPTION

The 9536B is a 2″ diameter flat face, end window, 10 stage venetian blind tube with Antimony Caesium (CsSb) secondary emission surfaces which are free from gain variation with tube current. The tube is overcapped with a Bakelite diheptal base type B14A as used on many photomultipliers produced in the U.S.A.

<table>
<tr><th colspan="3">BRIEF SPECIFICATION</th></tr>
<tr><td>AMPERES/LUMEN</td><td>MAX VOLTAGE</td><td>DARK CURRENT</td></tr>
<tr><td>20</td><td>1500</td><td>0.02μA</td></tr>
<tr><td>50</td><td>1700</td><td>0.05μA</td></tr>
<tr><td colspan="3">MINIMUM PHOTOSENSITIVITY:— 30 MICROAMPERES/LUMEN</td></tr>
</table>

TECHNICAL DETAILS

When operated with uniform interstage potentials (linear dynode chain) and an overall voltage of 1700 volts the peak output current of the E.M.I. 9536B is linear to 10 mA with an overall gain of 50 amperes per lumen. With non-uniform interstage potentials (non-linear dynode chain), of 400 volts between dynodes $D_8 — D_9$, $D_9 — D_{10}$ and D_{10} — ANODE, the overall sensitivity for a typical tube at 2200 volts is 200 amperes per lumen and a linear peak current of 50mA is obtainable.

The standard 9536B has an Antimony-Caesium photocathode of S11 spectral response, and gives extremely good energy resolution when used in a scintillation gamma ray spectrometer (Ca 4% for light pulses equivalent to Cs^{137} in Thallium activated Sodium Iodide corresponding to 7½% for a good 1½″ × 2″ crystal).

The time spread at 1700 volts is 16 m μsec. At 2200 volts, with the non-uniform interstage potentials (400 volts between the last three stages), the time spread is 14 m μsec and the rise time (10% to 90%) 6 m μsec. The gain and output current available makes this tube suitable for coincidence work.

The sensitivity of the tube to magnetic fields is low and screening from the earth's field is not necessary. When operated in high magnetic fields a suitable screen should be used.

Tubes with Quartz window BiAgCs(S10) and the E.M.I. "S" type cathode (suitable for low energy counting) are available as listed below. Type 9553 with S1 cathode is available to special order, but with uncertain delivery.

VARIATIONS OF 10 STAGE PM TUBE TYPE 9536

Type No.	Nominal Seated Height	Cathode Type	Window Material	Description and Applications
9554	124mm	S10	Glass	Colour television Flying Spot scanners (Red channel). Spectrophotometers, etc.
9552	143mm	S13	Fused Quartz	U.V. sensitive to near 1600 AU. For use in spectrophotometers and in gas scintillation counters.
9553	124mm	S1	Glass	Sensitive to 12000 AU. Near-Infra-red spectrophotometers, infra-red flying spot scanners, infra-red communication systems, etc.
9536S	124mm	E.M.I. 'S' Type	Glass	CsSb photocathode processed for max. blue sensitivity consistent with extremely low thermionic emission. Suitable for C^{14} and H^3 counting in liquid scintillators.

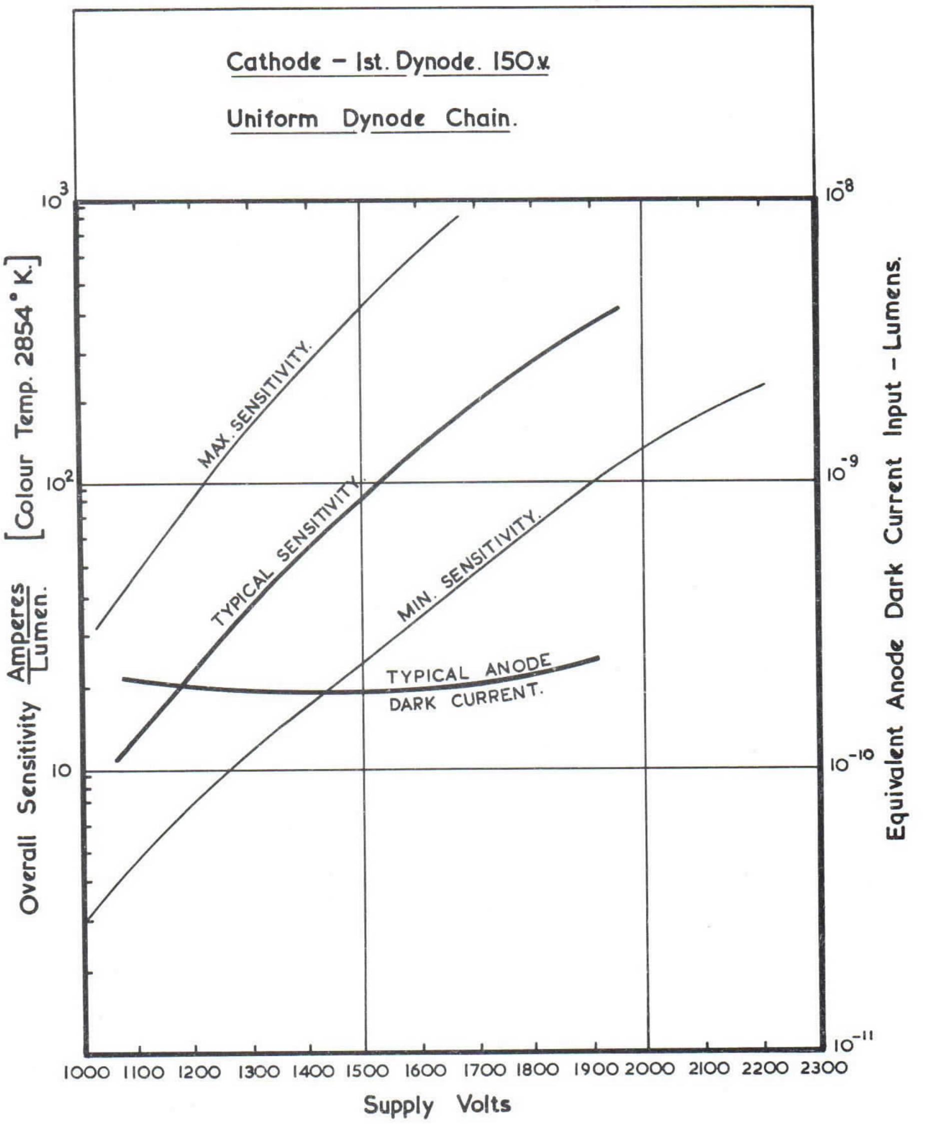
E.M.I. 9536 BASE CONNECTIONS

PIN NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ELECTRODE	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D_9	D_{10}	A	—	—	K

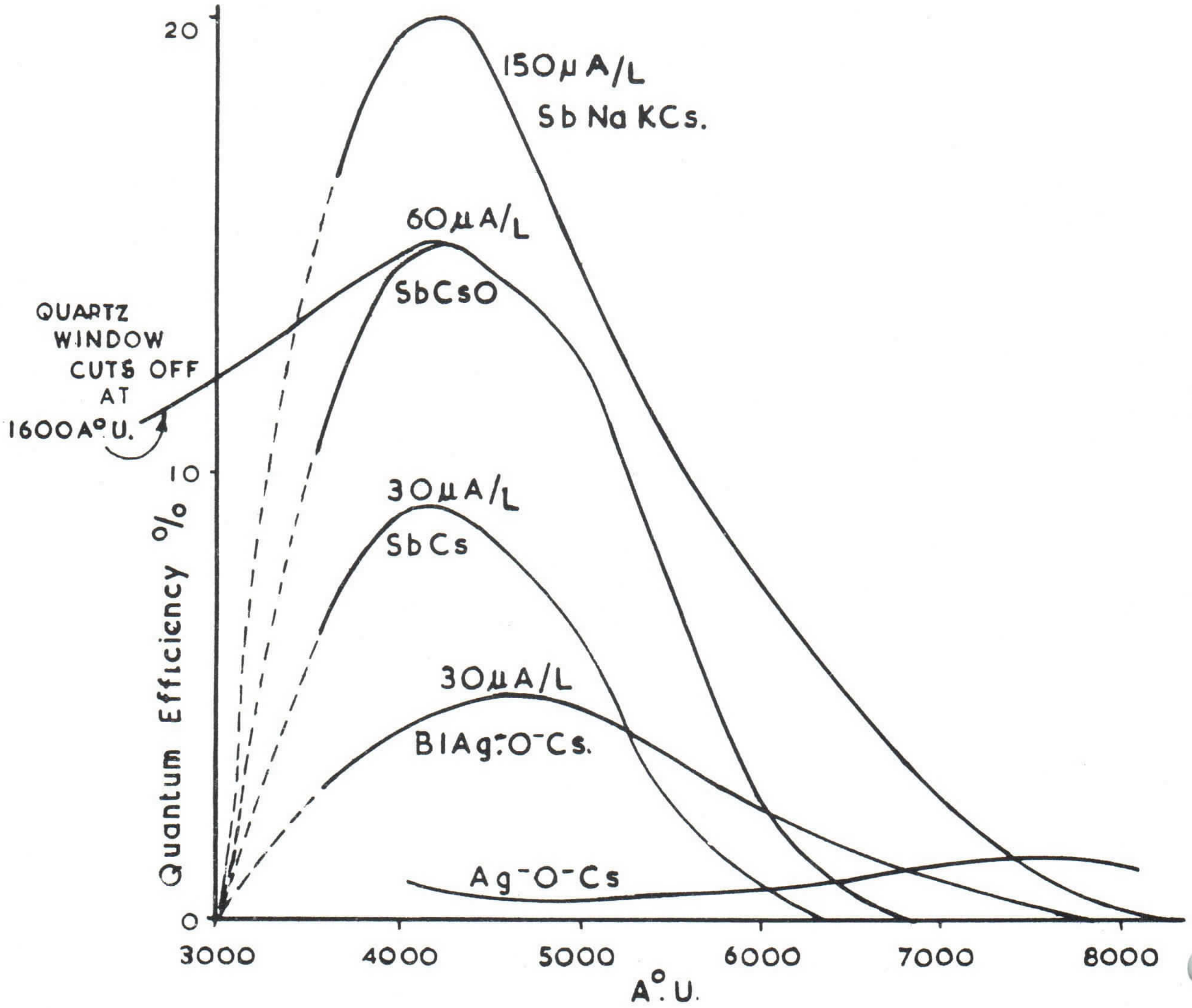
D:—DYNODE A:—ANODE K:—CATHODE

The base connections and overall dimensions of the E.M.I. 9536B are the same as the DuMont 6292 and the R.C.A. 6342, for which the 9536B is a direct replacement.

P.M. TUBE - TYPE: 9536 B.



SPECTRAL SENSITIVITY
OF
SEMI-TRANSPARENT PHOTOCATHODES



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PHOTOMULTIPLIER TYPE 9545B

The 9545 is a 12 inch diameter flat face end window multiplier phototube having 11 venetian-blind type dynodes with highly stable CsSb secondary emission surfaces, and relatively slow rise time.

The cathode is of the Sb-Cs-O (S11) type having maximum sensitivity in the blue region of the spectrum, the peak quantum efficiency at 4200A.U. being typically 12½%. Optimum collection of electrons from the cathode into the large area first dynode is accomplished by adjustment of the potential applied to a focusing electrode. This efficient collection, coupled with the high photosensitivity and high D1 gain, render the tube particularly useful for many scintillation counter applications, especially those in which large phosphors are used. The high gain and high output current decrease the need for following amplification. It is desirable to operate the tube in suitable magnetic shields in order to avoid disturbing effects from stray magnetic fields. A variant with a tri-alkali cathode may be supplied to special order (9545TA).

The tube is fitted with a 15 pin glass base, type B15B, and may be supplied complete with a P.T.F.E. Socket if required. An overcapped version, using a diheptal base, may be supplied to special order.

CHARACTERISTICS

Mechanical - (See figure overleaf)

Bulb diameter :	360mm. max.	Cathode diameter :	250 mm min.
Neck diameter :	56mm. max.	Seated height :	360 ± 6 mm.

Electrical			Max.	Typical	Min.
Photocathode sensitivity		µA/L		50	30
200 Amps/Lumen	* Voltage	V	2400	2000	
	Dark current	µA	4.0	0.5	
200 Amps/Lumen	+ Voltage	V		2900	
	Dark current	µA		2.0	

* C-D1 voltage 750V. Focus Electrode ca 250V -ve to D1, uniform dynode chain

\+ C-D1 voltage 750V. Focus Electrode ca 250V -ve to D1, uniform dynode chain to D9, 400V per stage D9-D10, D10-D11, D11-Anode. 50 mA peak linear output

Ratings C - D1 : 1,000V max. C - Anode : 3,000V max.

Mean anode current : 1mA max.

Mean anode dissipation : 1.0W max.

Ambient Temperature : 75°C max. -80°C min.

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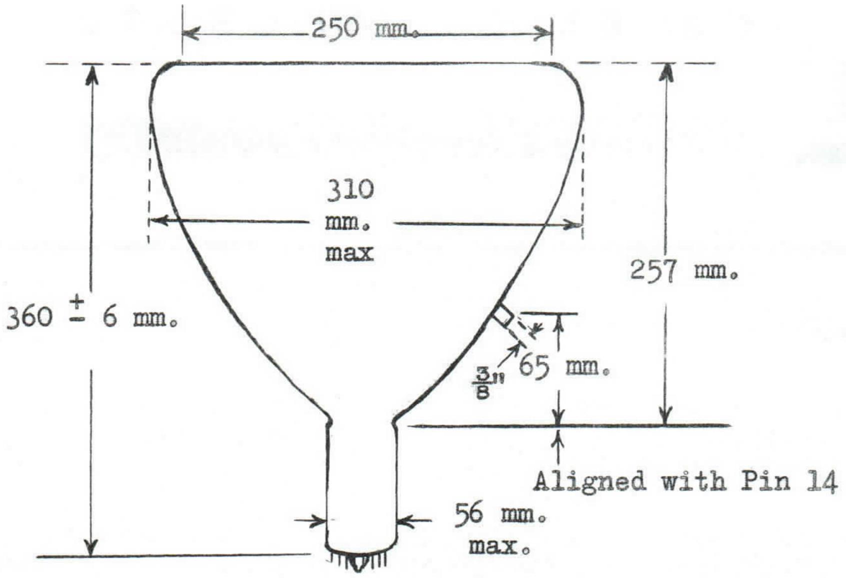
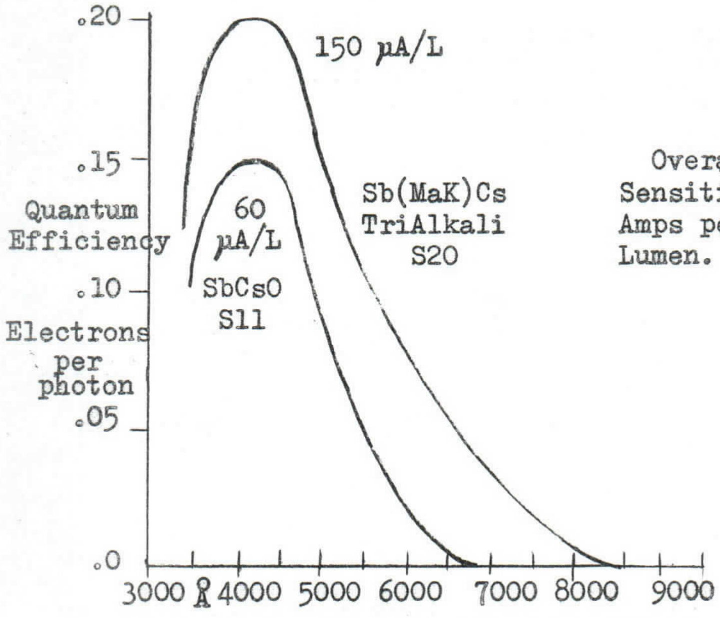
18.10.60.



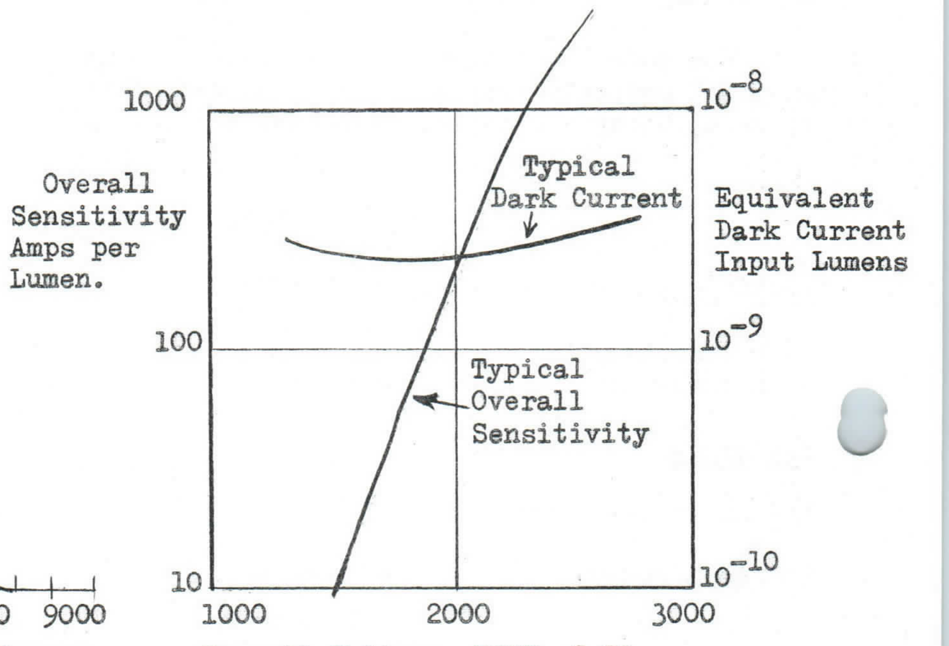
Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Side
Dynode	IC	1	3	5	7	9	11	A	10	8	6	4	2	F	–	C

IC : Internal Connection A : Anode

C : Cathode F : Focus Electrode.



Approximate Spectral Response Curves.



Overall Voltage 750V C–Dl.
Focus Electrode Adjusted (ca 250V –ve to D.l.)

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PHOTOMULTIPLIER TUBE TYPE 9553B

The 9553B is a 2" diameter flat face, end window, photomultiplier tube, having 10 stage venetian blind type dynodes with highly stable AgMgOcS secondary emission surfaces.

The semi transparent photocathode is of a special type with a high infra-red sensitivity. The tube has a bakelite diheptal base, type B14A.

CHARACTERISTICS

MECHANICAL :	Average tube diameter	2"
	Cathode diameter	1½" min.
	Average overall length	5⅝"
	Average seated height	4⅞"

ELECTRICAL :	Average cathode sensitivity :	18 µA/L.
	Average overall sensitivity :	105 Volts per stage 9 A/L
	Dark current :	15 µA.
	Average current amplication :	105 Volts per stage = 5 x 10^{-5}

Voltage cathode to D1 should be twice the average between succeeding stages.

RATINGS :	Peak cathode current :	20 µA
	Average Anode current :	5 mA
	Peak Anode current :	25 mA
	Anode dissipation :	0.5 watts
	Peak Anode dissipation :	2.5 watts
	Max. overall voltage :	1600
	Max. volts last D.10 to A. :	200 volts
	Max. volts C to D.1. :	400 volts

EC8/28
27.6.60.

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TRI-ALKALI PHOTOMULTIPLIER TUBE TYPE 9558B

The 9558B is a 2" diameter flat faced, end window, photomultiplier tube with a 44 m.m. cathode and 11 stage venetian blind dynodes coated with CsSb secondary emitting material.

The end window, semi-transparent photocathode is of the tri-alkali S20 type. Compared with the S11 type photocathode the tri-alkali photocathode has an enhanced red response which enters the near infra red, coupled with a lower dark current.

This tri-alkali photocathode may be operated at -180°C.

The 9558 is also available with a quartz window for operation in the ultra-violet.

The tube has a glass base type B19A.

CHARACTERISTICS (see figure on reverse of sheet)

Bulb diameter : 51.5 m.m. max.

Seated height : 140 ± 3 m.m.

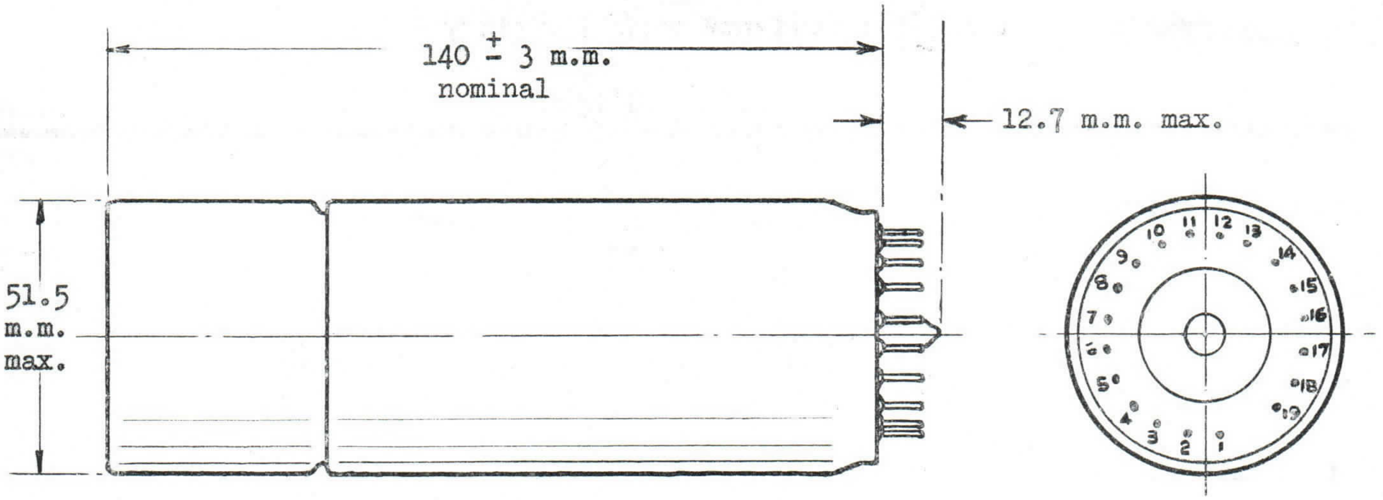
Cathode dia. : 44 m.m.

ELECTRICAL.

		Typical	Max.	Min.
Photocathode sensitivity	µA/L	150		100
Overall sensitivity at 20 Amps/Lumen	Voltage V.	1100		
	Dark current µA	0.004		
Overall sensitivity at 200 Amps/Lumen	Voltage V.	1450	2,000	
	Dark current µA	0.01*	0.02	
Overall sensitivity at 500 Amps/Lumen	Voltage V.	1650		
	Dark current µA	0.02		

The above measurements are taken with a dynode chain giving 150V cathode - D_1 and a uniform inter-stage potential thereafter.

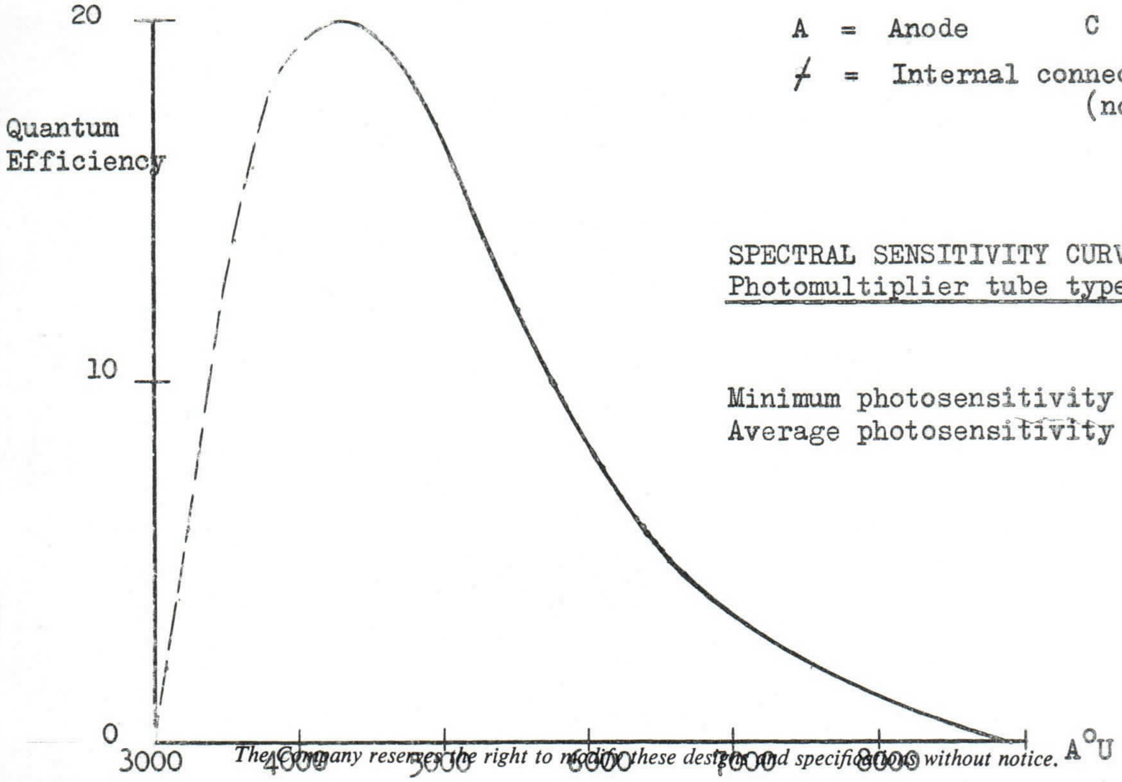
* After exposure of the tube to light, the dark current in any photomultiplier tube will tend to be higher than its equilibrium value in the dark; with this tube type however, equilibrium is approached quite rapidly, with an initial half time of about 10 minutes.



B19A - BASE CONNECTIONS																			
Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Electrode	D1	D3	D5	D7	D9	D11	∤	A	∤	D10	D8	D6	D4	D2	∤	∤	∤	∤	C

A = Anode C = Cathode

∤ = Internal connections.
(not to be used).



SPECTRAL SENSITIVITY CURVE of
Photomultiplier tube type 9558

Minimum photosensitivity = 100 µA/L
Average photosensitivity = 150 µA/L

The Company reserves the right to modify these designs and specifications without notice.

EC8/30
8.7.60.

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PHOTOMULTIPLIER TYPE 9578B

The 9578B is a 3 inch diameter flat face end window multiplier phototube having 10 venetian-blind type dynodes with highly stable CsSb secondary emission surfaces.

The semi-transparent photocathode is of the Cs-Sb-O (S11) type, with maximum sensitivity in the blue region of the spectrum, an average tube having a quantum efficiency of 12½ to 15% at 4200A.U. Optimum collection of electrons from the cathode into the large area first dynode is accomplished by adjustment of the potential applied to a focussing electrode.

A high average photosensitivity coupled with efficient electron collection and a high value of D1 gain combine to render the tube particularly useful for scintillation gamma-ray spectroscopy with a 2½ inch NaI-Tl crystal.

The ability of the design to provide a high gain with a peak output linear to 50mA, and a rise time of 6 millimicroseconds makes it suitable for coincidence work.

The tube is overcapped with a medium shell di-heptal 14 pin base, type B14A, and will operate as a replacement for DuMont photomultiplier tube type 6363.

CHARACTERISTICS

Mechanical (See fig. on reverse of sheet)

Bulb diameter:	3 ± 3/32 Inches.	Neck diameter:	2 ± 1/16 Inches
Overall Length:	6⅛ ± 3/16 "	Seated height:	5⅜ ± 3/16 "
Cathode diameter:	2½ inches minimum	Window material:	Pyrex

Electrical

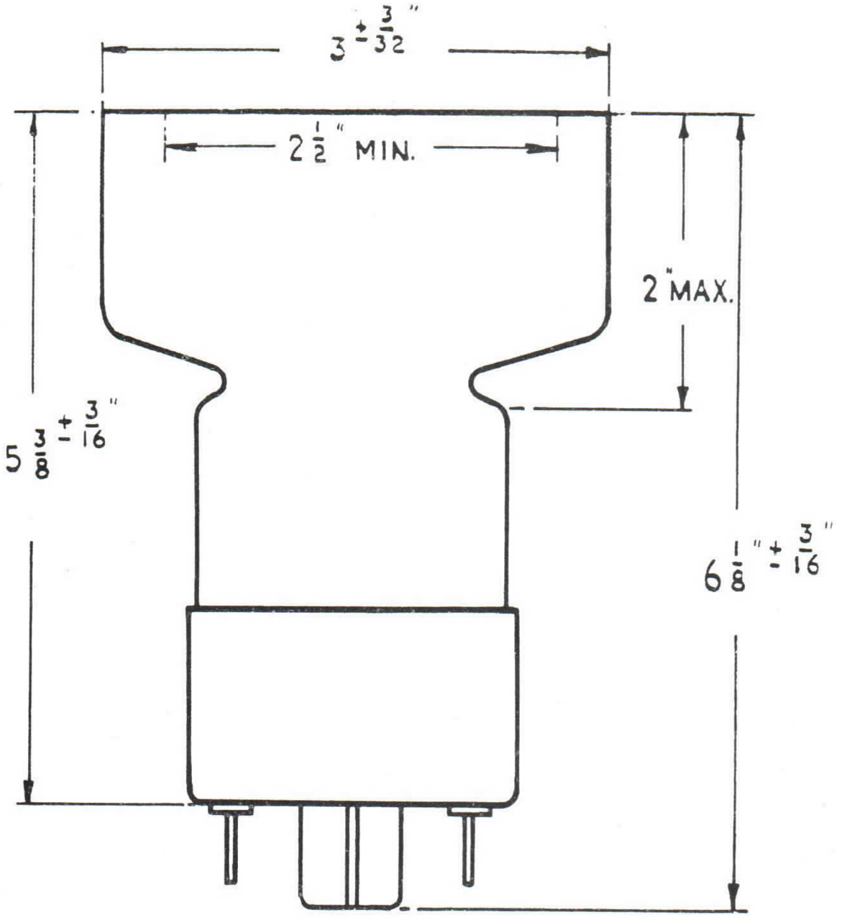
			Max.	Typical	Min.
Photocathode sensitivity.		µA/L		50	30
Overall sens'y 50 Amps/lumen	Voltage *	V.	1700	1400	
	Dark current	µA	0.1	0.02	
200 Amps/lumen	Voltage *	V.		1750	
	Dark current	µA		0.1	
2000 Amps/lumen	Voltage ∅	V.		2600	
	Dark current	µA		2.0	

* 300V cathode-D1, then uniform dynode chain. Focus electrode adjusted. (ca 100V negative to D1).

∅ 300V cathode to D1, then uniform chain to D8, then 400V per stage D8-D9, D9-D10, and D10-Anode, giving 50 mA linear peak output. Focus electrode adjusted.

Ratings. (Max.) C-D1 350V. Max. C-Anode. 2800V Max. Mean anode current 1mA. Mean anode dissipation, 1.5W Max. Ambient temperature 75°C Max. - 80°C Min.

TD



BASE CONNECTIONS. A – ANODE F – FOCUS ELECTRODE C – CATHODE

PIN No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ELECTRODE	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	A	–	F	C

THIS BASIC TUBE IS AVAILABLE IN THE FOLLOWING FORMS :-

9578 B.	S 11 CATHODE, FOR GENERAL USE.
9578 S.	E.M.I. S CATHODE, WITH LOW THERMIONIC EMISSION FOR LOW ENERGY SCINTILLATION COUNTING.
9578 X.	AS 9578 B BUT NESA COATING ON INNER SURFACE OF WINDOW TO ALLOW OPERATION AT -180°C.
9578 U.	AS 9578 B BUT NOT OVERCAPPED. FITS B 15 B TEFLON SOCKET. SEATED HEIGHT 5⅜" MAX.
9578IR.	Ag Mg O DYNODES, Ag – Cs – O CATHODE (S1) WITH INFRA RED SENSITIVITY.

The Company reserves the right to modify these designs and specifications without notice.

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PHOTOMULTIPLIER TYPE 9579B

The 9579B is a 5 inch diameter flat face end window multiplier phototube having 10 venetian blind type dynodes with highly stable CsSb secondary emission surfaces.

The semi-transparent photocathode is of the Cs-Sb-O (S11) type, with maximum sensitivity in the blue region of the spectrum, an average tube having a quantum efficiency of 12½ to 15% at 4200A.U. Optimum collection of electrons from the cathode into the large area first dynode is accomplished by adjustment of the potential applied to a focussing electrode, which for most tubes will be found to require 1/3 of the C-D1 voltage, (negative to D1).

A high average photosensitivity, coupled with efficient electron collection and a high value of D1 gain combine to render the tube particularly useful for scintillation gamma ray spectroscopy with a 4¼ inch NaI-Tl crystal.

A high gain is available from the tube, with peak output currents linear up to 50mA.

The tube is overcapped with a medium shell di-heptal 14 pin base, type B14A, and will operate as a replacement for DuMont photomultiplier tube type 6364.

CHARACTERISTICS

Mechanical (See figure on reverse of sheet)

Bulb diameter:	5 inches Max.	Neck diameter:	2 ± 1/16 inches
Overall length:	7½ ± 3/16 inches	Seated height:	6¾ ± 3/16 inches
Cathode diameter:	4⅜ inches Min.	Window material:	Pyrex.

Electrical

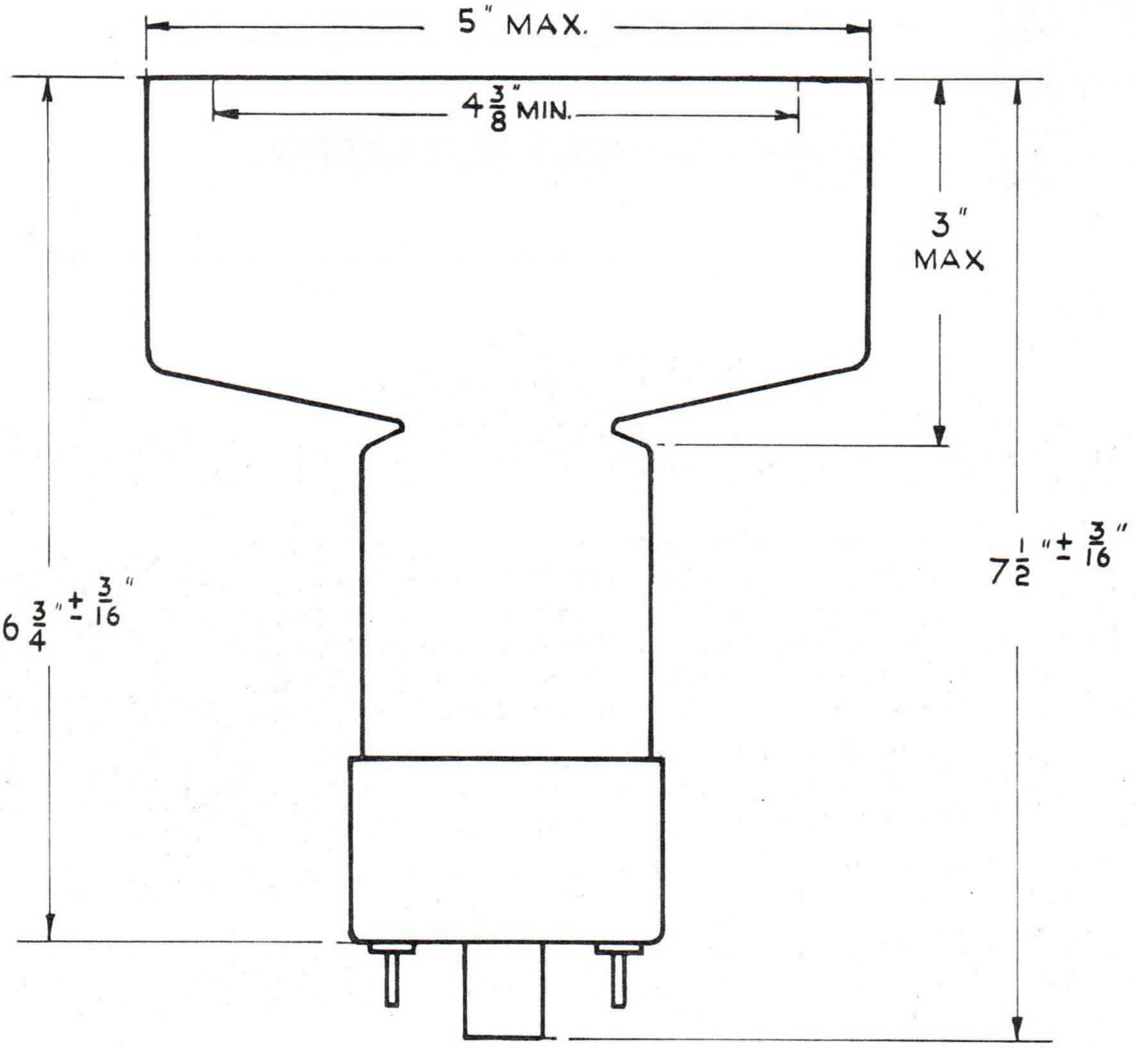
			Max.	Typical	Min.
Photocathode sensitivity		µA/L		50	30
Overall sens'y 50 Amps/lumen	* Voltage	V	1800	1400	
	Dark current	µA	0.1	0.04	
200 Amps/lumen	* Voltage	V		1800	
	Dark current	µA		0.2	
2000 Amps/lumen	ϕ Voltage	V		2600	
	Dark current	µA		3.0	

* 450V cathode-D1, then uniform dynode chain. Focus electrode adjusted. (ca 100V negative to D1)

ϕ 450V cathode to D1, then uniform chain to D8, then 400V per stage D8-D9, D9-D10, D10-Anode, giving 50mA linear peak output. Focus electrode adjusted.

Ratings. (Max). C-D1. 500V max. C-Anode, 2800V max.

Mean anode current 1mA max. Mean anode dissipation 1.5W max. Ambient temperature 75°C max. - 80°C min.



BASE CONNECTIONS. A - ANODE. F - FOCUS ELECTRODE. C - CATHODE.

PIN Nº	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ELECTRODE	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	A	-	F	C

THIS BASIC TUBE IS AVAILABLE IN THE FOLLOWING FORMS:-

9579 B.	S II CATHODE – FOR GENERAL USE.
9579 U.	AS 9579 B, BUT NOT OVERCAPPED. FITS B15B TEFLON SOCKET. SEATED HEIGHT 6 3/4" MAX.
9582 B	Ag Mg DYNODES & S1 (Ag Cs O) CATHODE WITH INFRA RED SENSITIVITY.

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PHOTOMULTIPLIER TYPE 9583B

The 9583B is a 5 inch diameter flat face end window multiplier phototube having 11 venetian-blind type dynodes with highly stable CsSb secondary emission surfaces.

The cathode is of the Sb-Cs-O (S11) type having maximum sensitivity in the blue region of the spectrum, the peak quantum efficiency at 4200A.U. being typically 12½ to 15%. Optimum collection of electrons from the cathode into the large area first dynode is accomplished by adjustment of the potential applied to a focusing electrode. This efficient collection, coupled with the high photosensitivity and high D1 gain, render the tube particularly useful for many scintillation counter applications, including gamma ray spectroscopy with a 110mm diameter NaI-Tl crystal. The high gain and high output current decrease the need for following amplification.

The tube is overcapped with a medium shell di-heptal 14 pin base, type B14A, and will operate as a replacement for Dario photomultiplier tube 54AVP.

CHARACTERISTICS

Mechanical (See fig. overleaf)

Bulb diameter:	130mm max.	Cathode diameter:	111mm min.
Neck diameter:	54mm max.	Seated height:	210 ± 5mm.

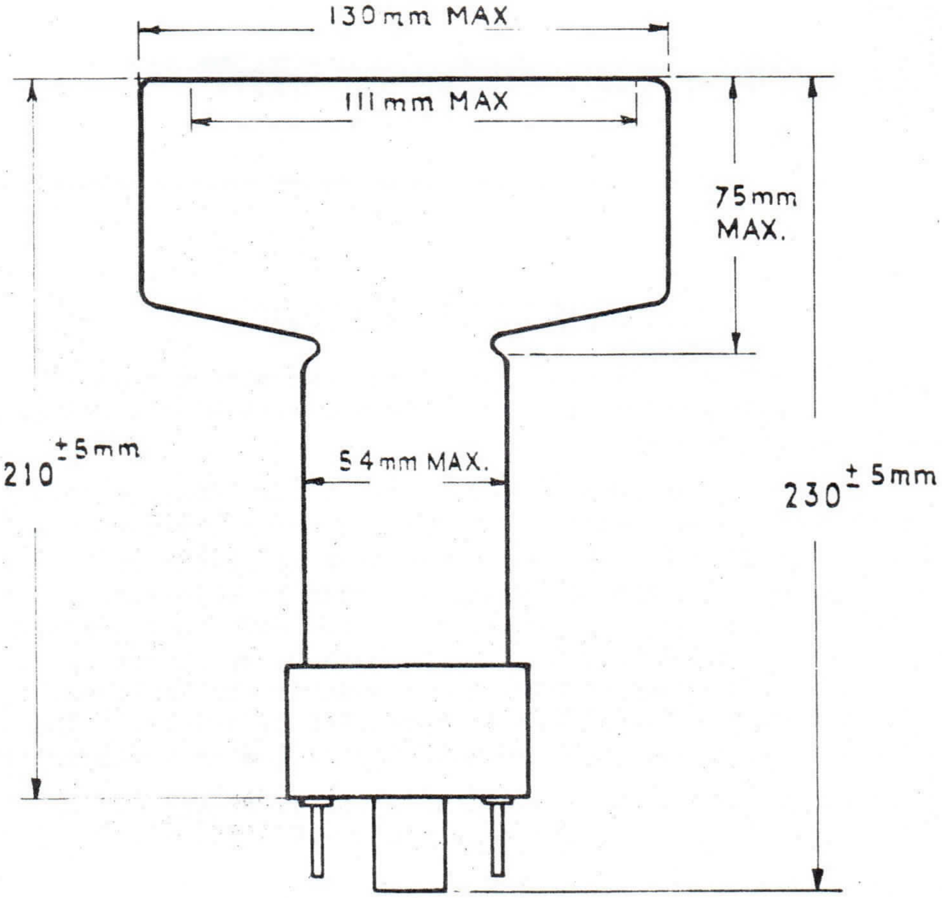
Electrical

			Max.	Typical	Min.
Photocathode sensitivity		μA/L		50	30
Overall sensitivity 100 Amperes per lumen	* Voltage	V	1800		
	Dark current	μA	0.2		
250 Amps/lumen	* Voltage	V	2100	1800	
	Dark current	μA	0.5	0.20	
2000 Amps/lumen	+ Voltage	V		2600	
	Dark current	μA		2.0	

* C-D1 voltage 450V, Focus Electrode 100V -ve to D1, uniform dynode chain.

\+ C-D1 voltage 450V, Focus Electrode 100V -ve to D1, uniform dynode chain to D9, 400V per stage D9-D10, D10-D11, D11-Anode. 50mA peak linear output.

Ratings C-D1 500V max. C-Anode 2800V max.
Mean anode current 1mA max. Mean anode dissipation 1.5W max.
Ambient Temperature. 75°C max. -80°C min.



BASE CONNECTIONS :- F = FOCUSING ELECTRODE : A = ANODE : C = CATHODE.

PIN Nº	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ELECTRODE	F	D2	D4	D6	D8	D10	A	D11	D9	D7	D5	D3	D1	C

THIS BASIC PHOTOMULTIPLIER TUBE IS AVAILABLE IN THE FOLLOWING TYPES.

9583 B S 11 CATHODE. FOR GENERAL SCINTILLATION COUNTING.

9583 IR S 1 CATHODE.

9530 B UNCAPPED VERSION. GLASS BASE FITTING B 15 B PTFE SOCKET. SEATED HEIGHT 170mm MAX.

The Company reserves the right to modify these designs and specifications without notice.

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PHOTOMULTIPLIER TUBE TYPE 9584B

The 9584B is a 2 inch diameter flat face, end window multiplier phototube having 11 venetian blind type dynodes with highly stable CsSb secondary emission surfaces.

The semi-transparent photocathode is of the Cs-Sb-O (S11) type with a maximum sensitivity in the blue region of the spectrum, an average tube having a peak quantum efficiency of 12½ to 15% at 4200A.U. The large area of the first dynode provides excellent collection of the photoelectrons without the necessity for adjustment of a focusing electrode, and this feature, coupled with the high D1 gain and the high sensitivity of the cathode make the tube particularly useful for gamma ray scintillation spectroscopy. The ability of the tube to provide peak output currents linear to more than 50mA, coupled with a high gain of nearly 10^8 and a rise time for very short light pulses of 6musec, make it suitable for coincidence work.

Even at the large value of overall sensitivity which is obtainable, the dark current of the tube is extremely low, and this suggests its use in a wide range of spectro-photometric applications.

The tube is overcapped with a medium shell di-heptal 14 pin base type B14A, and will operate as a replacement for the Dario (Philips) photomultiplier tube type 53AVP.

CHARACTERISTICS

Mechanical (See fig. on reverse of sheet)

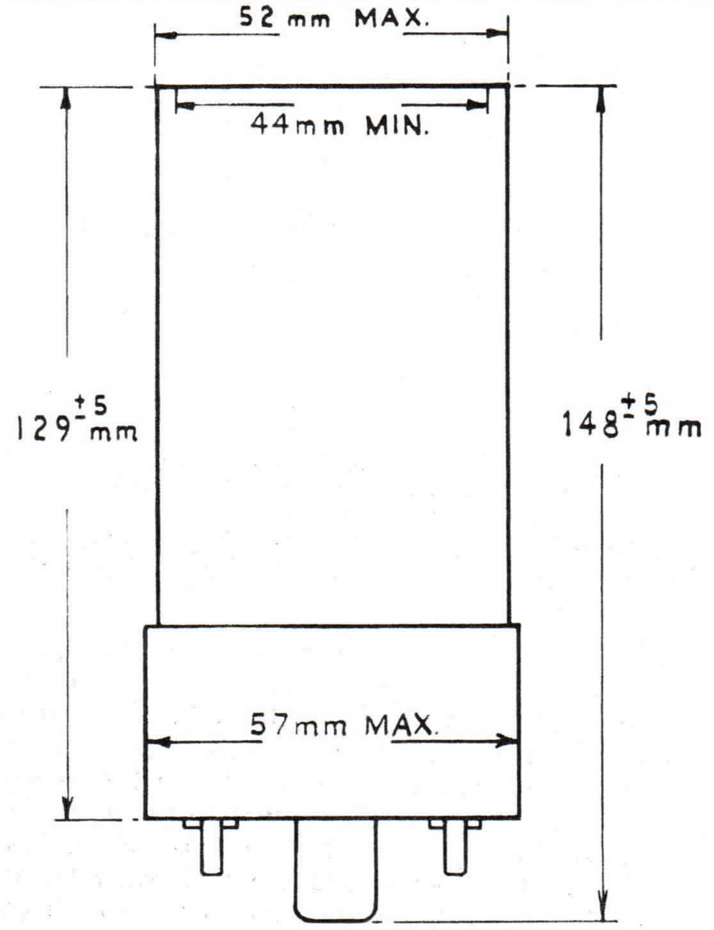
Bulb diameter:	52 mm max.	Neck diameter:	52 mm max.
Overall length:	148 ± 5mm	Seated height:	129 ± 5mm
Cathode diameter:	44 mm Min.	Window material:	Pyrex or Lime Soda.

Electrical			Max.	Typical	Min.
Photocathode sensitivity		μA/L		50	30
Overall sens'y 60 Amps/lumen	* Voltage	V	1500	1350	1100
	Dark Current	μA	0.03	0.01	-
200 Amps/lumen	* Voltage	V	1800	1500	1250
	Dark Current	μA	0.1	0.04	-
2000 Amps/lumen	+ Voltage	V		2400	
	Dark Current	μA		0.4	

* 150V C-D1. Uniform Dynode Chain thereafter.

150V C-D1. Uniform Dynode chain to D9. Then 400V D9-D10, D10-11, & D11-Anode giving 50mA linear peak output.

Ratings C - D1. 300V Max. C - Anode. 2800V Max.
Mean anode current 1mA max. Mean anode dissipation 1.5W Max.
Ambient temperature 75°C Max. - 80°C Min.



BASE CONNECTIONS

PIN Nº	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ELECTRODE	D1	D2	D4	D6	D8	D10	A	D11	D9	D7	D5	D3	D1	C

A = ANODE C = CATHODE

THIS BASIC TUBE IS AVAILABLE IN THE FOLLOWING FORMS:-

9584 B	S 11 CATHODE, FOR GENERAL USE.
9584 S	E.M.I. S CATHODE, WITH LOW THERMIONIC EMISSION FOR LOW ENERGY COUNTING.
9584 X	AS 9584 B, BUT N.E.S.A. COATING ON INNER SURFACE OF WINDOW TO ALLOW OF OPERATION AT -180° C.
6097 B	AS 9584 B, BUT NOT OVERCAPPED. FITS B 15 B TEFLON SOCKET. SEATED HEIGHT 115 mm MAX.

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PHOTOMULTIPLIER TUBE TYPE 9592B

The 9592B is a high-gain small-diameter photomultiplier, (1.15" max) having 11 dynodes of the box and grid type which are coated with CsSb secondary emitting material.

The end window semi-transparent photocathode is of the BiAgCsO - S10 type, with maximum sensitivity in the blue region of the spectrum, but extending in the red to 8,000 Å U. The glass of the tube window is transparent in the UV down to 2,000 Å U and the wide spectral range, coupled with the low dark current makes the tube particularly suitable for spectrophotometry. The blown window surface is not optically plane.

The tube has a glass base, type B14B, which fits a PTFE socket of small outside diameter, so that the whole assembly may be fitted into a tube of 1.2" inside diameter.

CHARACTERISTICS

Mechanical (see figure on reverse of sheet).

Bulb diameter - 1.15" max. (29.3 m.m.)

Cathode diameter - 15/16" (23 m.m.)

Seated height - (112 ± 3 m.m.)

Window material - UV transmitting glass - 1mm thick.

ELECTRICAL

		Max.	Typical	Min
Photocathode sensitivity	μA/L		35	25
Overall sensitivity 20 Amps/lumen	Voltage V		950	
	Dark current μA		0.002	
200 Amps/lumen	Voltage V	1500	1350	
	Dark current μA	0.10	0.02	

Measurements made with C-D1 100V, dynode chain with voltage D9-D10, D10-D11 and D11-Anode twice that between D1-D2, D2-D3, etc.

RATINGS

C-D1 150V max.

C-Anode 2000V max.

Overall sensitivity 3000 Amps/lumen

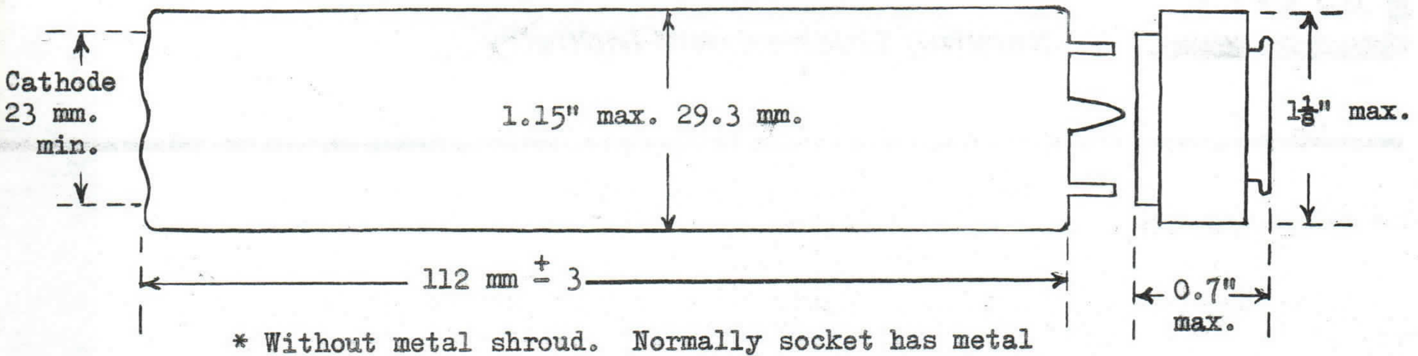
Mean anode current - 1mA max.

Mean anode dissipation - 1.0 W

Ambient temperature - 75°C max. -80°C min.

EC 8/41
7.10.60

DIMENSIONS FOR 9592B

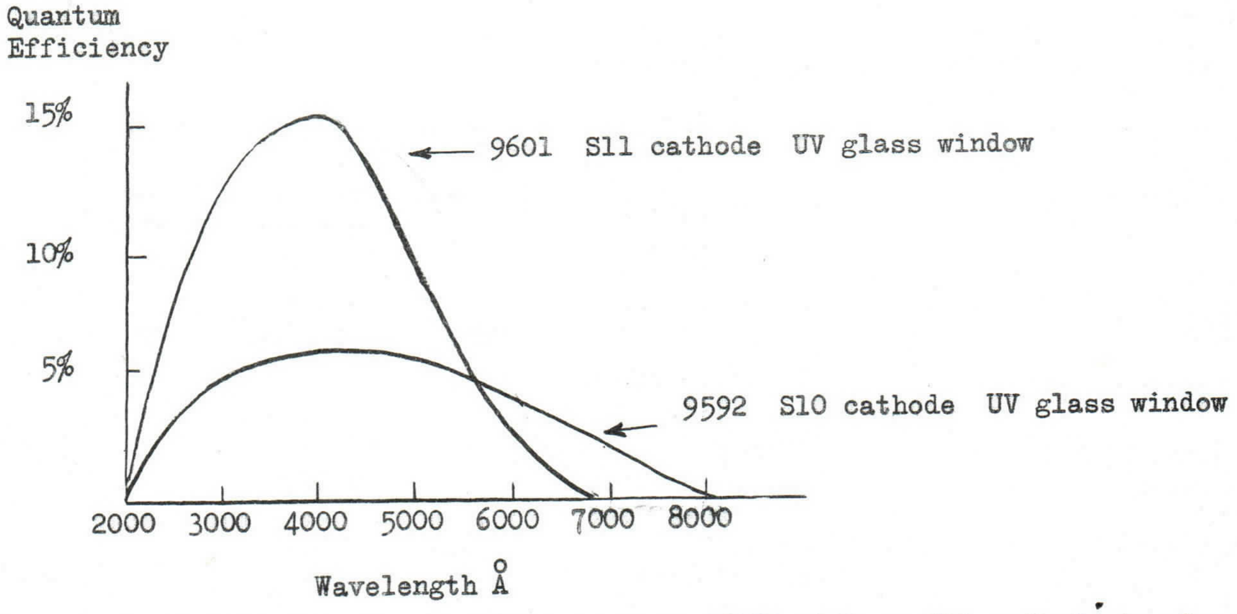


* Without metal shroud. Normally socket has metal shroud with two fixing holes $1\frac{3}{8}$" apart, .156" dia.

BASE CONNECTIONS

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Electrode.	-	3	5	7	9	11	A	10	8	6	4	2	C	1

A = Anode C = Cathode



A variant of this tube is available as type 9601B with an S11 cathode in place of the S10 photocathode and would then typically give 200 A/L at 1100V, with a dark current of .01µA.

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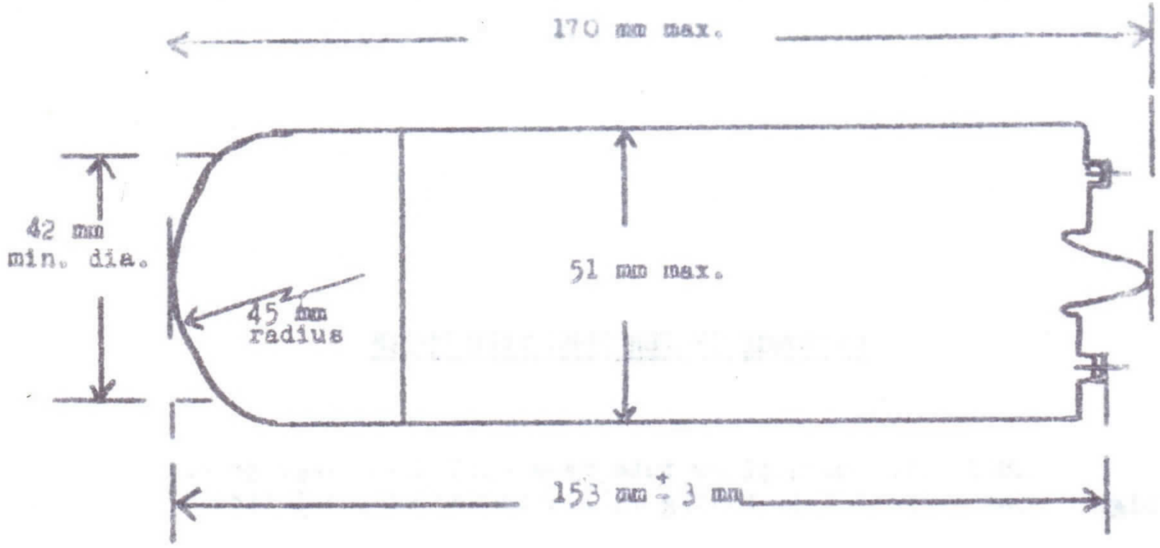
PHOTOMULTIPLIER TUBE TYPE 9593B

E.M.I. Photomultiplier tube type 9593B is a high gain, high output current tube having millimicrosecond resolution.

A fast linear focused structure of 14 dynodes of AgMgoCs fitted with an extra focus wire to reduce space charge limitation, provides an output current linear to about 200 mA, with a saturated value of about 1 ampere. A curved cathode of S11 type and a system of focussing electrodes forming spherical equipotentials gives a small spread in transit time for electrons from various parts of the cathode into D1, so that an overall time spread of ca 4 musec. (width at half maximum) is obtained, with a rise time of 2½ musec. with the whole cathode illuminated.

Average Characteristics.

Dimensions	See figure overleaf
Cathode type	S11
Cathode Sensitivity	45 u A/L
Overall sensitivity	2000 A/L
Overall voltage for 2000 A/L	2000 V
Dark current at 2000 A/L	1 uA
Overall voltage for high output current condition	2500 V



19 Pin glass Base

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Dynode	1	3	5	7	9	11	13	Focus Wire	A	14	12	10	8	6	4	2	-	F	C

C = Cathode   A = Anode   F = focus electrode (between C & D1.)

For high, linear, output current, the focus wire should be connected to D14, and a dynode chain, proportions as below, should be used:

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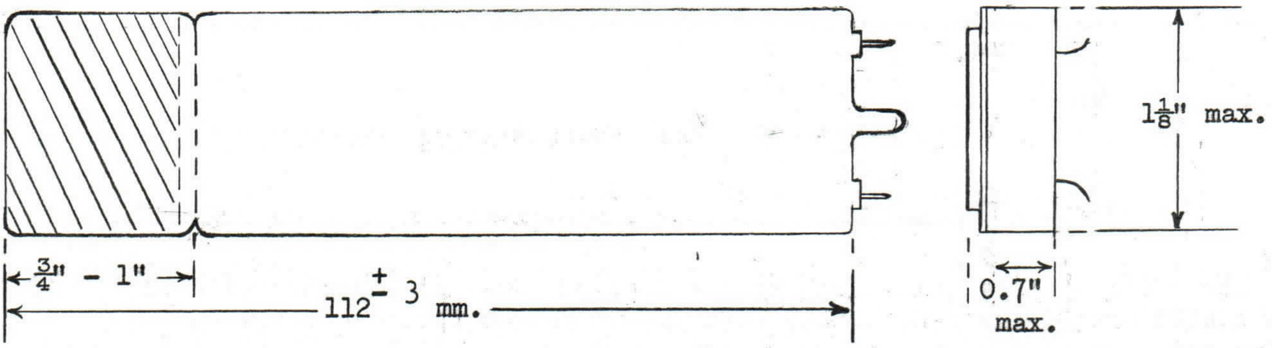
LARGE CATHODE AREA, SMALL DIAMETER PHOTOMULTIPLIER
TUBE TYPE 9600B

The 9600B is a $1\frac{1}{8}$" diameter Photomultiplier tube with 11 Box and Grid SbCs coated dynodes, having a semi-transparent photocathode over the end window and down the cylindrical sides for ca $\frac{3}{4}$". This gives a total cathode area of ca 20cm^2, making the tube very suitable for large area α and β scintillation probes for health physics work,* and for immersion into a liquid phosphor. The cathode is of the SbCs (E.M.I. S. Type) with reduced red sensitivity.

When first put into use, the dark current will be found to be very high, but rapidly decreased to the operating value over a period of 30 mins. or so.

* See I.R.E. Trans. Nucl. Sci. NS7, p44, 1960.

Cathode type	:	E.M.I. S.	(Similar to S.11 but of reduced red sensitivity).
Photosensitivity	:	30 µA/L	Typical
Overall Sensitivity	:	200 A/L	
Overall Voltage for 200 A/L	:	1250V	Typical
Dark Current at 200 A/L	:	0.05µA	Typical

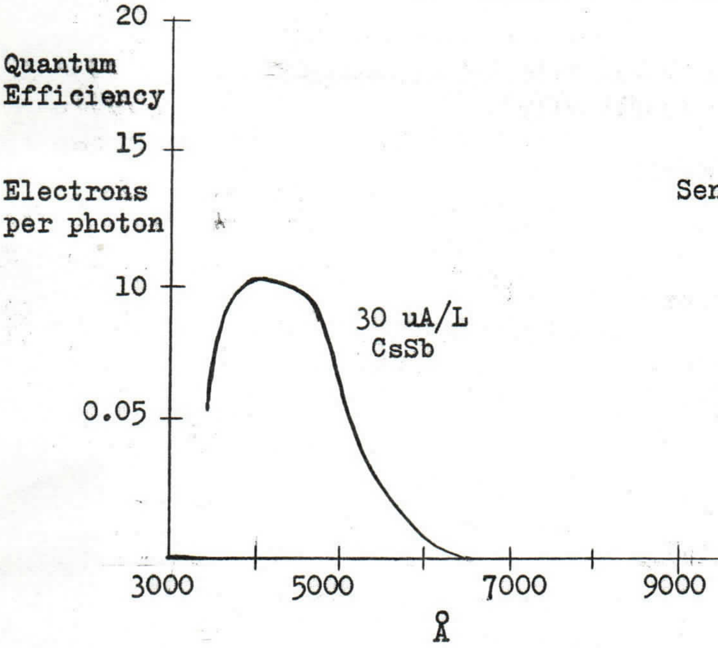


(Photocathode extends over shaded area, including end window.)

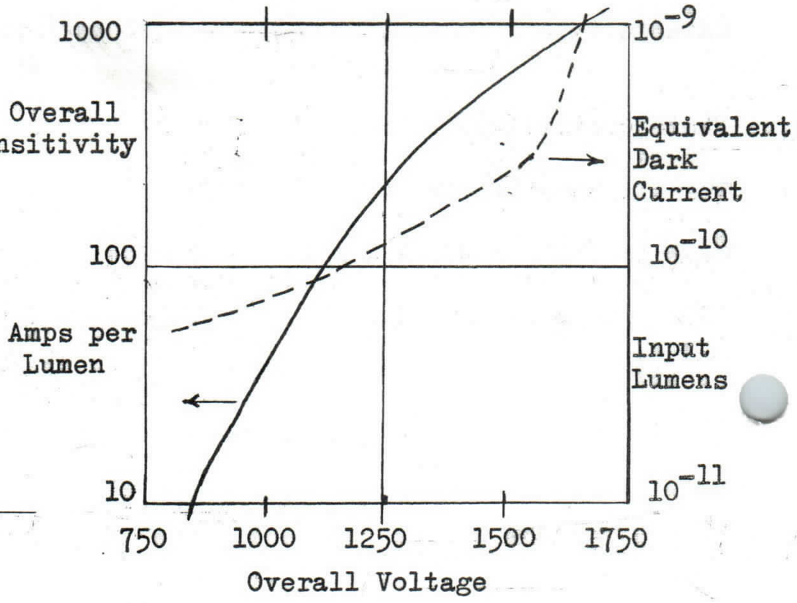
BASE CONNECTIONS

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Electrode	-	D3	D5	D7	D9	D11	A	D10	D8	D6	D4	D2	C	D1

A = Anode   C = Cathode



Approximate Spectral Response Curve



Typical Characteristics

EC8/18-R
7.11.60.

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PARTICLE MULTIPLIER TYPE 9603.

These particle counters consist of a "Venetian Blind" dynode system and the dynodes, made from oxidised silver magnesium, are assembled into a fifteen stage secondary emission multiplier.

When operated in a vacuum of 10^{-5} mm. mercury or better, an overall voltage of between 3,000 **and** 4,000 volts may be applied between the first dynode and the anode; equal inter-stage voltages being provided by a linear dynode resistance chain. Under these conditions an overall gain of between 10^6 and 10^7 may be obtained, although the actual value depends to some extent on the previous history of the electrode system. If the gain is found to be low it may be largely restored by running an electrical discharge in oxygen through the dynode system.

When soft X-rays are incident on the first dynode, low energy electrons are emitted. A proportion of these are accelerated onto the second dynode where they produce secondary electrons which in turn produce tertiary electrons at the third dynode, and so on. These primary signals are observed at the anode as a positive charge which may be counted by conventional means. The efficiency of detection varies with X-ray energy but may be around 10^{-3}.

When electrons are incident on the first dynode, a secondary emission ratio of about 5 is obtained for an incident energy around 500-700 V and this falls off to below unity at energies above a few keV. Heavy particles will give a good secondary emission ratio at energies above 10 keV.

BASE CONNECTIONS. B/9A. ~~B19B~~ Socket.

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Electrode.	-	-	D1	D3	D5	D7	D9	D11	D13	D15	A	D14	D12	D10	D8	D6	D4	D2	-

EC8/27
16.6.60.

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9607B

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PHOTOMULTIPLIER TUBE TYPE 9607B

The 9607 is a 44 m.m. cathode, 11 stage venetian blind photomultiplier tube with a 2" diameter soda glass envelope. This tube has been designed to work over a wide range of temperatures with very low dark current for applications such as bore hole logging.

The end window semi-transparent photocathode in tube type 9607B is of the multi-alkali type, modified for high temperature operation. The dynodes are coated with Ag Mg O secondary emitting material.

The tube has a glass base, type B19A. If required a socket can be supplied with the tube.

CHARACTERISTICS :

Mechanical	:	See figure on reverse of sheet
Bulb diameter	:	51.5 m.m. max
Seated height	:	140 ± 3 m.m. nominal
Cathode diameter	:	44 m.m. min
Overall length	:	155 m.m. max.
Average photocathode sensitivity	:	10 µA/L (for early samples)
Average overall sensitivity	:	25 A/L at 3,000 volts.

At 3,000 Volts :

Dark current in range 0°C to 100°C is masked by leakage of 10^{-9}A approx.

Dark current at 150°C is 5 x 10^{-8}A approx.

BASE CONNECTIONS : Type B19A.

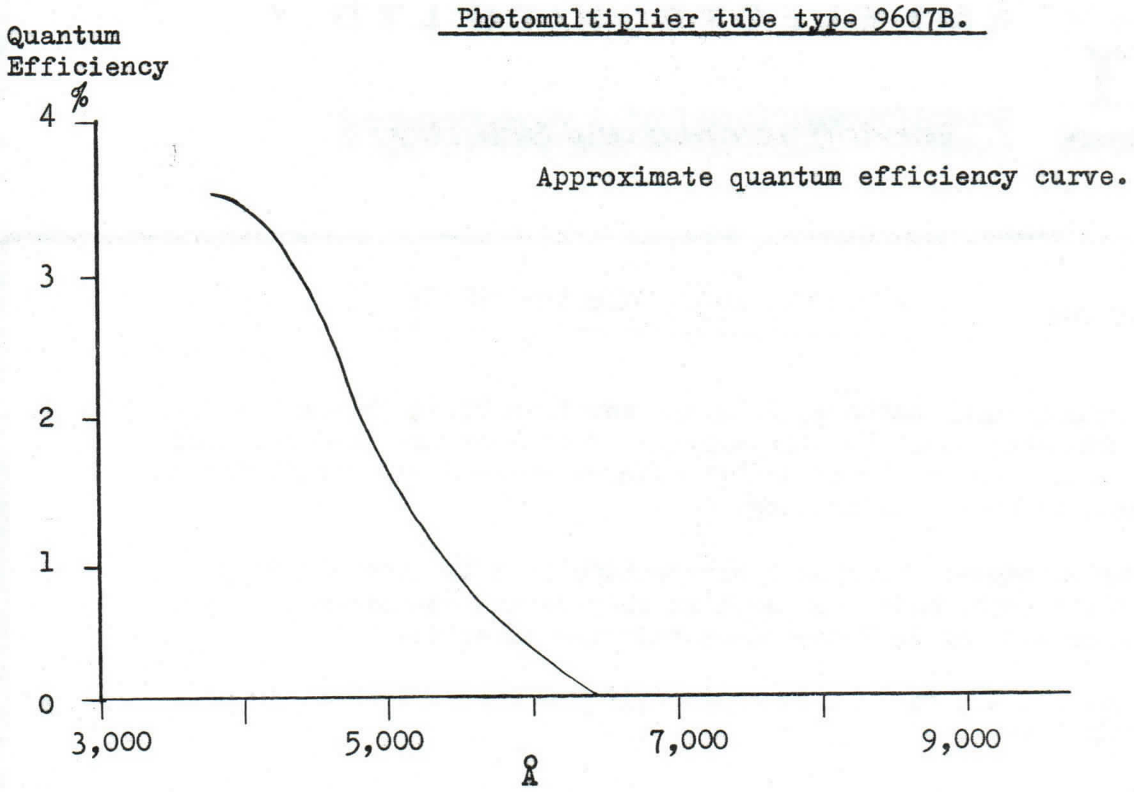
Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Electrode	D1	D3	D5	D7	D9	D11	IC	A	IC	D10	D8	D6	D4	D2	IC	IC	IC	IC	C	SP

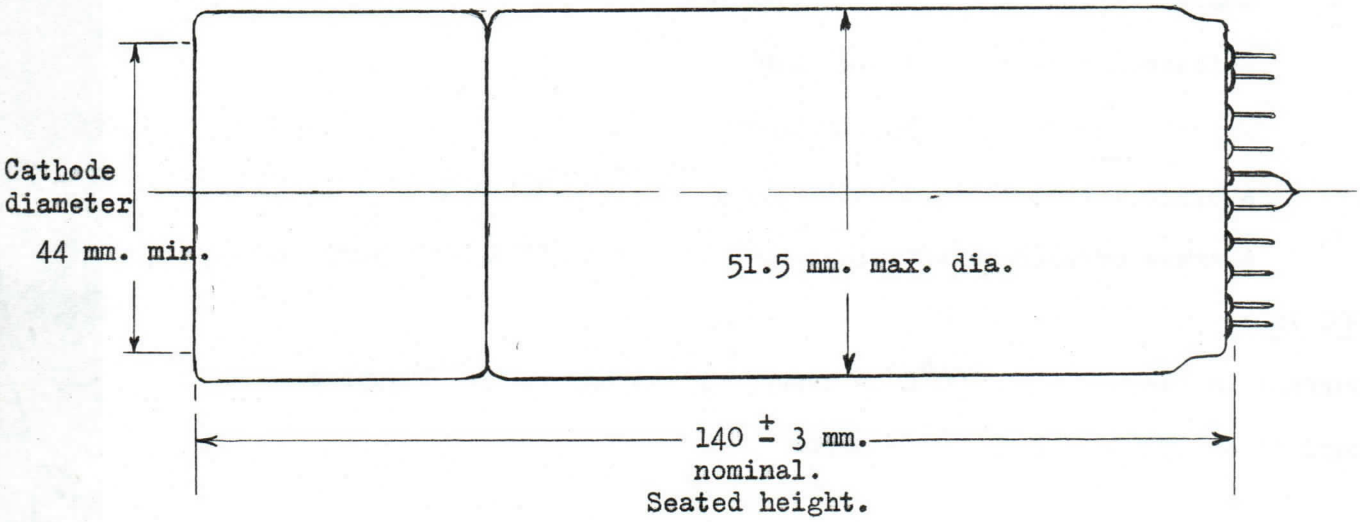
A = Anode
SP = Short Pin

C = Cathode
IC = May be internally connected

EC8/12
26.1.61.

Photomultiplier tube type 9607B.





EC8/12
26.1.61.

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Preliminary Data

7" Photomultiplier Tube type 9623

The E.M.I. Photomultiplier tube type 9623 is a 7" diameter, flat face, end window multiplier phototube with blue sensitive, semi-transparent S11 cathode and 11 stage venetian blind (SbCs coated) dynode system.

Primarily intended for use with large scintillation crystals, e.g. in whole body monitors, the tube has been designed to give maximum efficiency and uniformity of collection of photoelectrons into D1. To this end, focus electrodes are fitted, which must be adjusted to give optimum results.

The tube has a glass base, type B15B, which fits a P.T.F.E. (Teflon) socket, available from E.M.I.

CHARACTERISTICS

Mechanical See figure on reverse of sheet.

Bulb Dia.	190 mm. max ($7\frac{1}{2}$")	Cathode Dia.	172 mm. ($6\frac{3}{4}$")
Seated height	224 mm. ± 5 mm.	Window material	- Pyrex.

Electrical

		Max.	Typical	Min.
Photocathode sensitivity	µA/L		50	30
Overall sensitivity	+ Voltage V	3000	2000	-
200 Amps/Lumen	Dark current µA	1.0	0.1	-

+ C - D_1 750V F_1 - D_1 600V F_2 - D_1 ca 10V (Adjust) Uniform dynode chain thereafter.

Ratings

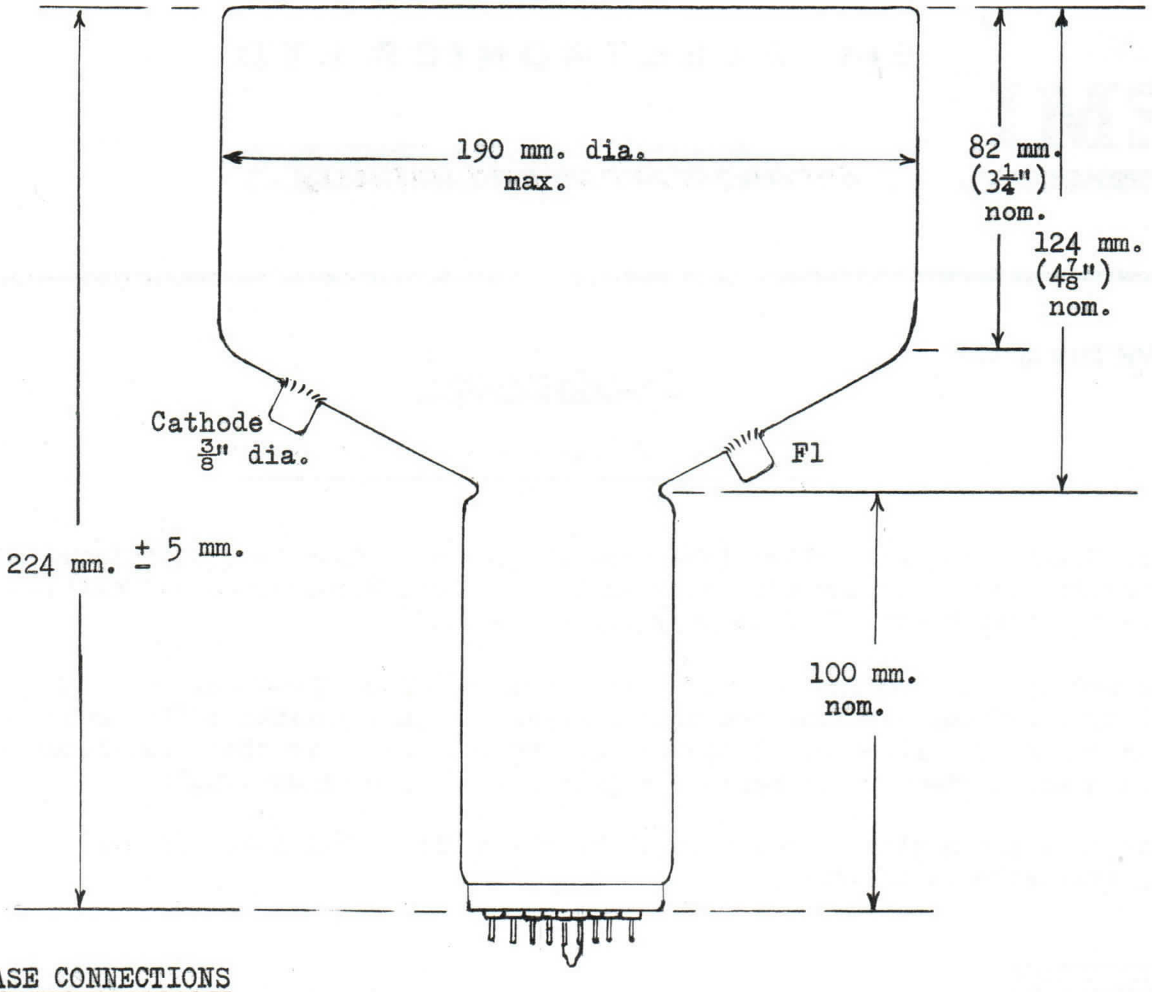
C - D1 : 1,000V max.

C - Anode : 3,000V max.

Mean anode current : 1mA max.

Mean anode dissipation : 1.0W max.

Ambient Temperature : 75°C max. -80°C min.



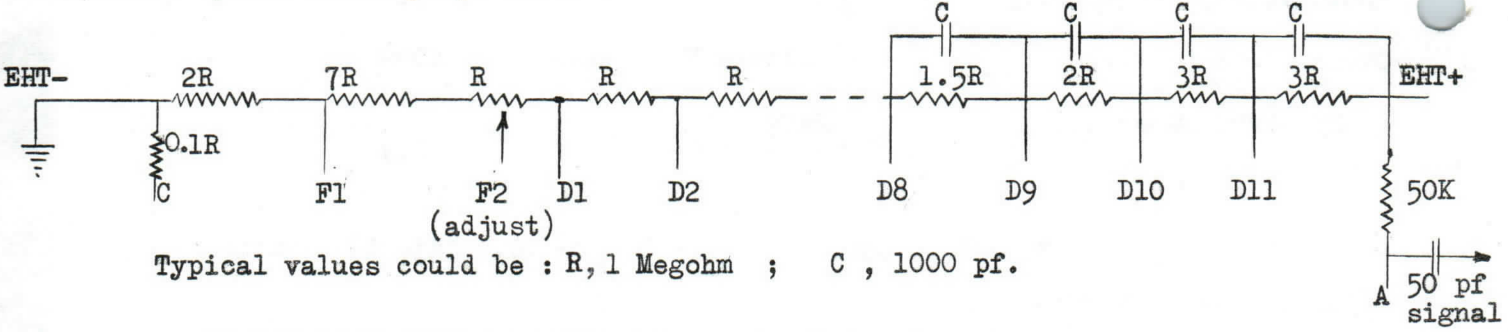
BASE CONNECTIONS

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Side	Side
Dynode.	IC	1	3	5	7	9	11	A	10	8	6	4	2	F	-	Cathode	F_1

IC : Internal Connection   A : Anode

F : Focus Electrode

Recommended dynode chain proportions :



Typical values could be : R, 1 Megohm ; C , 1000 pf.

EC8/49
7.11.60.

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EMI PHOTOMULTIPLIER TUBE TYPE 9660B

The 9660B is a 9-stage squirrelcage design having a UV-transmitting glass envelope. The opaque photocathode is sensitive to radiation incident upon it through the side wall of the envelope which transmits down to 2000 Å. The spectral response of the caesium-antimony cathode is of the S5 type with a peak between 3000 and 4000 Å and a long wavelength cut-off between 6500 and 7000 Å. The 9660B is intended for use with low-level UV and visible radiation in spectrometer and similar applications. The tube has a pressed glass base, type B14B, which fits a PTFE socket, available from EMI Electronics Ltd.

The basic type is available overcapped with a small-shell submagnal 11-pin base (type 9661B), when it will operate as a direct replacement for the RCA type 1P28, or with a quartz envelope (type 9662) which extends the UV sensitivity to below 1700 AU.

CHARACTERISTICS

Mechanical (See figure on reverse of sheet)

Bulb diameter	30.2 mm (1.2 in) max.	Overall length	89 mm (3.4 in) max.
Seated height	76 mm (2.9 in) max.	Cathode size	7.9 mm x 23.8 mm (0.31 in x 0.94 in)

Electrical

		Max.	Typical	Min.
Photocathode sensitivity	μA/lm		40	
Overall sensitivity at 1000V	A/lm		50	
Overall voltage	V	1250		
Dark current at 1000V	μA	0.06		
Equivalent dark current at 1000V	lm	1.25×10^{-9}		

Measurements are made with a uniform dynode voltage divider and with tungsten light from a lamp of colour temperature 2870° K.

Ratings

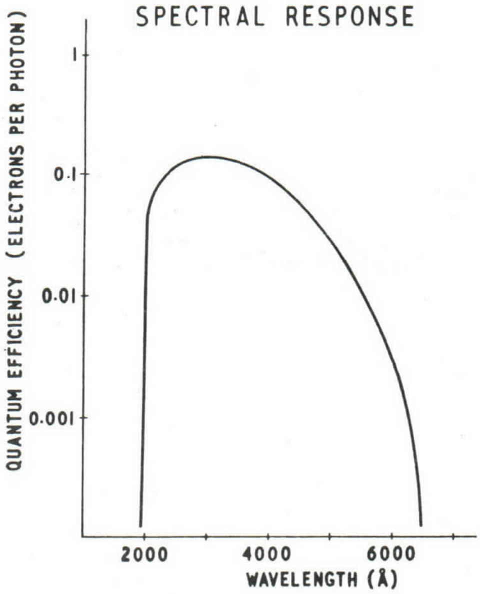
Cathode to anode 1250 V max. Mean anode current 0.5 mA max.
Operating temperature 75° C max. to -180° C min.

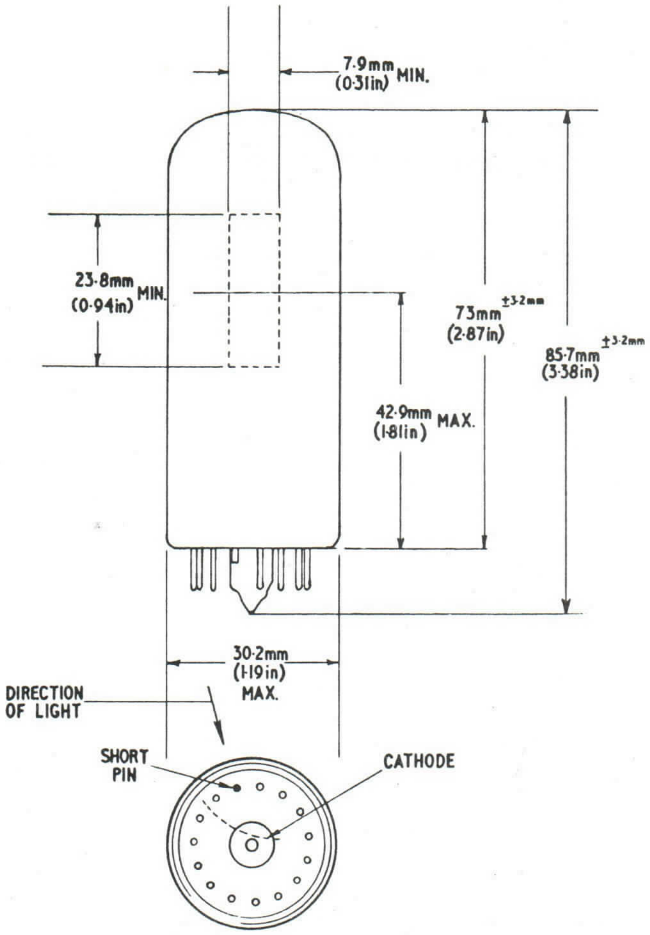
Base Connections

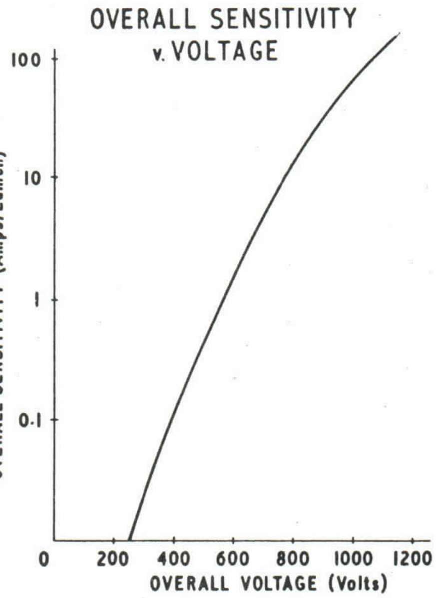
Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Electrode	C	D1	D2	D3	D4	D5	D6	-	D7	D8	D9	A	-	-

D = Dynode A = Anode C = Cathode

(Pins numbered clockwise from short pin, viewed from underside of tube. Blank pins must not be used for any connection).







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EMI PHOTOMULTIPLIER TUBE TYPE 9661B

The 9661B is a 9-stage squirrelcage design having a UV-transmitting glass envelope. The opaque photocathode is sensitive to radiation incident upon it through the side wall of the envelope which transmits down to 2000 Å. The spectral response of the caesium-antimony cathode is of the extended S5 type with a peak between 3000 and 4000 Å and a long wavelength cut-off between 6500 and 7000 Å. The 9661B is intended for use with low-level UV and visible radiation in spectrometer and similar applications. The tube is fitted with a small-shell submagnal 11-pin base and will operate in place of the RCA photomultiplier tube type 1P28.

CHARACTERISTICS

Mechanical (See figure on reverse of sheet)

Bulb diameter	30.2 mm (1.2 in) max.	Overall length	93.6 mm (3.7 in) max.
Base diameter	33.3 mm (1.3 in) max.	Cathode size	79.4 mm x 23.8 mm
Seated height	79.4 mm (3.1 in) max.		(0.31 in x 0.94 in)

Electrical

		Max.	Typical	Min.
Photocathode sensitivity	μA/lm		40	
Overall sensitivity at 1000V	A/lm		50	
Overall voltage	V	1250		
Dark current at 1000V	μA	0.06		
Equivalent dark current at 1000V	lm	1.25 x 10^{-9}		

Measurements are made with a uniform dynode voltage divider and with tungsten light from a lamp of colour temperature 2870° K.

Ratings

Cathode to anode 1250 V max. Mean anode current 0.5 mA max.
Operating temperature 75° C max. to -180° C min.

Base Connections

Small-shell submagnal Base B11A

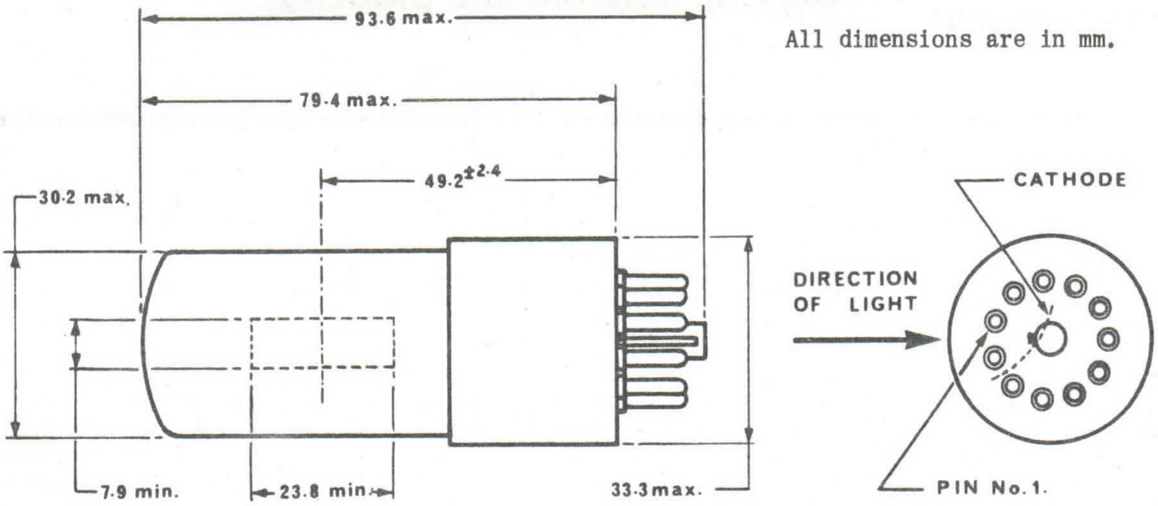
Pin No.	1	2	3	4	5	6	7	8	9	10	11
Electrode	D1	D2	D3	D4	D5	D6	D7	D8	D9	A	C

A = Anode C = Cathode D = Dynode

(Pins numbered clockwise from No. 1 pin, viewed from underside of tube)

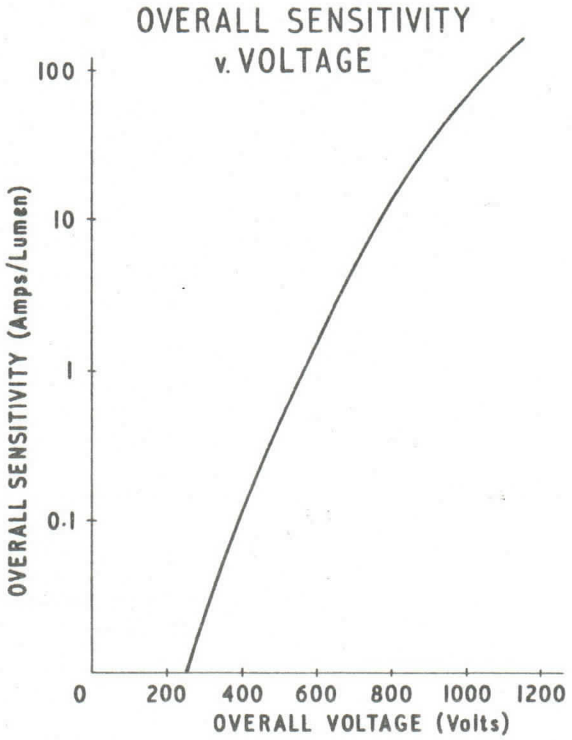
P086/1b
DS. 293/1

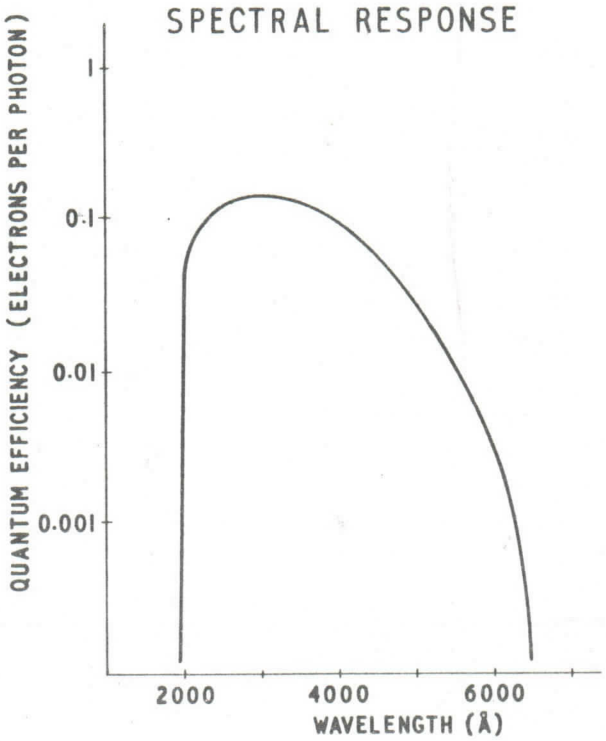
EMI PHOTOMULTIPLIER TUBE TYPE 9661B



All dimensions are in mm.

Centre line of bulb will not deviate more than 2° in any direction from the perpendicular erected at centre of bottom of base.





P086/2b
DS. 293/2

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EMI 4-STAGE IMAGE INTENSIFIERS TYPES 9692 & 9694

(Preliminary Data)

These are cascade image intensifiers of the phosphor/photocathode sandwich type employing magnetic focusing and all photocathodes are of the tri-alkali SbKNaCs type.

In the type 9692 the first stage incorporates the relatively fast zinc-oxide phosphor (P24) to enable the tube to be switched in 1 μsec. In subsequent stages the more efficient silver-activated zinc-sulphide (P11) phosphors are employed.

The type 9694 is a high gain low background tube with P11 phosphors throughout for night vision applications etc.

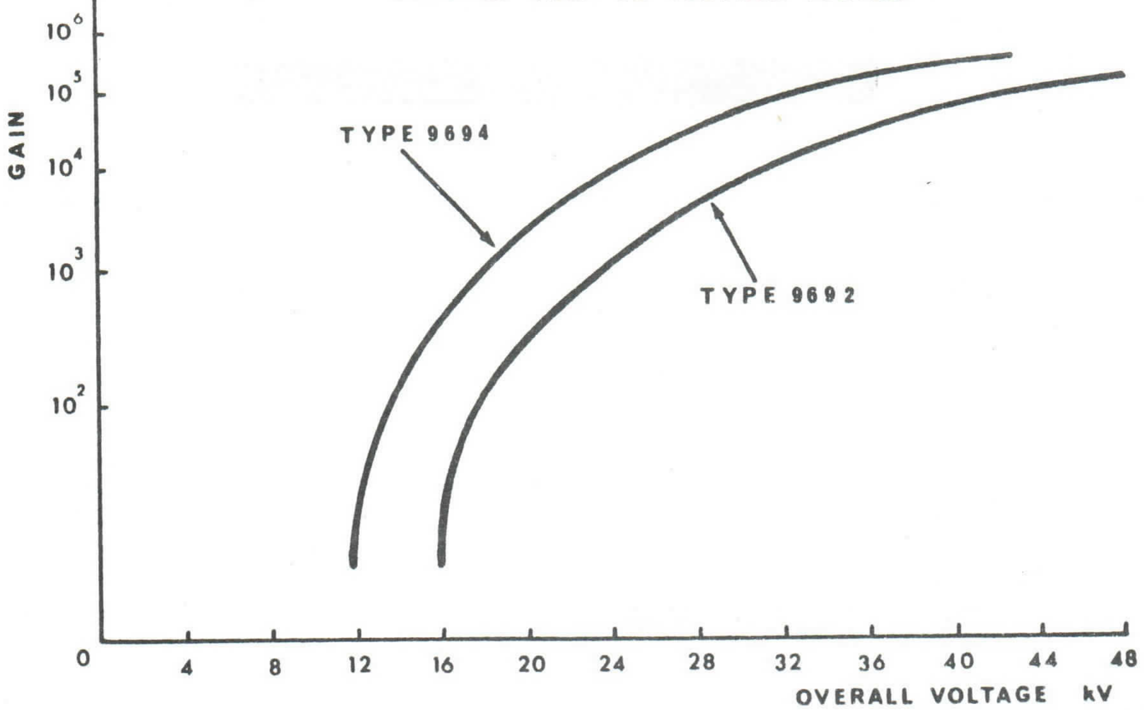
SPECIFICATIONS

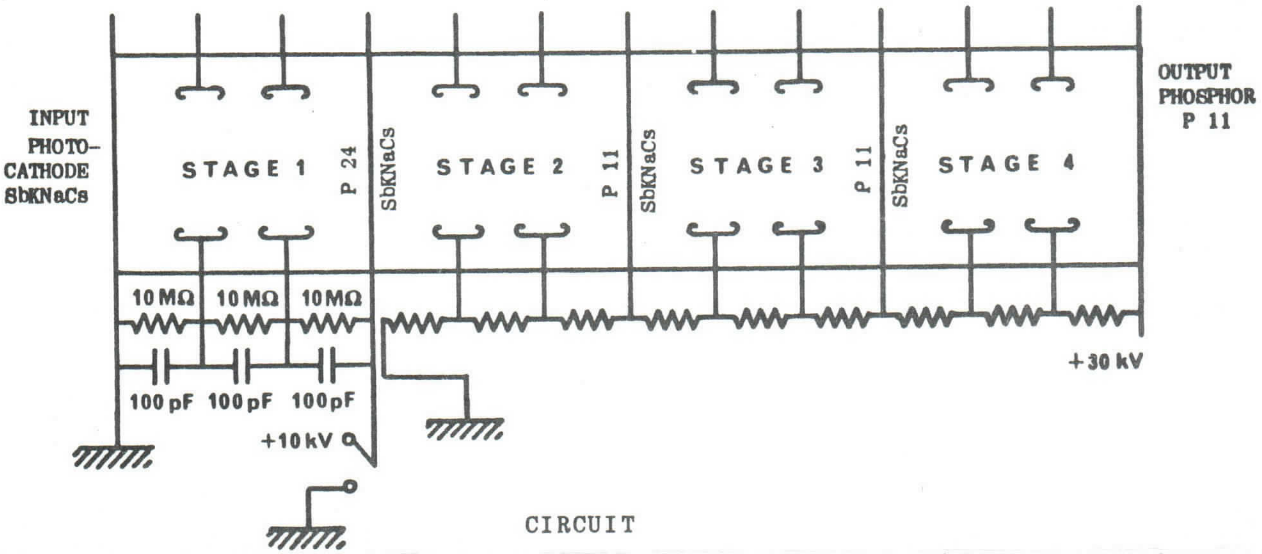
Overall length	304.80mm (12 in)
Overall diameter	95.25mm (3.75 in)
Focus coil	13 sections each 25.4mm (1 in) long and 152.4mm (6 in) internal diameter separated by 3.18mm (0.125 in) spacers. Each section consists of 1,200 turns of 22 SWG enamelled copper wire. Field required for single loop focusing 130 to 160 gauss.
End window material	Kodial
Input photocathode	Tri-alkali, 50.8mm (2 in) minimum useful diameter, sensitivity 100μA/lm.
Output phosphor	ZnSAg, useful diameter 50.8mm (2 in) minimum.

	TYPE	9692	9694
Typical light gain at 4,500Å 35 kV overall		2×10^4	2×10^5
Minimum light gain at 42 kV overall		2×10^5	8×10^5
Maximum overall voltage	kV	45	45
Maximum permissible mean output current	A	10^{-6}	10^{-6}
Electron dark current from photocathode at 42 kV overall	A/cm^2	10^{-16}	10^{-16}
Ion dark current at 42 kV overall	A/cm^2	10^{-17}	10^{-16}
Resolution	line pairs per mm	15 to 18	15 to 18

Water cooled aluminium foil coils are now in the final stages of development which give up to 500 gauss enabling 3 loop focusing which has been found to improve tube geometry and resolution.

TYPICAL GAIN vs VOLTAGE CURVES





CIRCUIT

Switching carried out by applying voltages as shown. Prior to event stages 1, 3 and 4 are on but stage 2 is off. When event arrives stage 1 is switched off and stage 2 on using hard valve circuitry by applying a negative pulse of 10kV to the first phosphor. The decay time of the phosphor is 1 μsec. and providing the switching pulse is much shorter, say 100 n. secs., the event will be further intensified by the last three stages sufficiently to enable photography of single electrons leaving the input photocathode. This is achieved by leaving the shutter of the camera open during the non-operative time.

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Magnetrons

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PACKAGED MAGNETRONS

The packaged magnetrons summarised below are for pulse operation in O, Q, J and X band. In all cases forced air cooling of the anode block is necessary to ensure that the maximum block temperature does not exceed 120°C.

The indirectly heated cathodes require the stated voltage to be applied for at least two minutes before anode voltage is applied.

Type	Out - put	Freq'y K Mc/s	Peak Input Av.Max K Volts		Pulse Length Av.Max μSec.	Peak Output Power Av.KW	Mean Input Power Av.Max Watts	P.F.ϕ 1.5:1 VSWR Max Mc/s	Heater Starting V	
			Av.Max K Volts	Av.Max Amps					V	A
R9551	WG26	80	10 12	5 8	0.2 0.3	2.5	- 25	-	9	3 *
R6138	WG22	34.5 - 35.3	13 16	10 15	0.2 0.5	18	50 90	40	6.3	2 *
R9515	WG22	"	14 16	15 25	0.2 0.5	35	85 120	80	6.3	4 *
R9509	WG18	16.2 - 17.2	14 18	20 30	0.5 1.0	50	- 400	10	6.3	7$\frac{1}{2}$*

* VH reduced to value specified on each tube within few seconds of application of anode voltage.

ϕ P.F. : Pulling figure with 1.5:1 VSWR.

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PACKAGED MAGNETRONS

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The indirectly heated cathodes require the stated voltage to be applied for at least two minutes before anode voltage is applied.

Type	Out-put	Freq'y kMc/s	Peak Input Av kVolts	Peak Input Max kVolts	Av Amps	Max Amps	Pulse Length Av µSec	Pulse Length Max µSec	Peak Output Power Av kW	Mean Input Power Av Watts	Mean Input Power Max Watts	P.F.ϕ 1.5:1 VSWR Max Mc/s	Heater Starting V	Heater Starting A	
✓ R9551	WG26	80	10	12	5	8	0.2	0.3	2.5	-	25	-	9	3	*
✓ R6138	WG22	34.5 - 35.3	13	16	10	15	0.2	0.5	18	50	90	40	6.3	2	*
✓ R9515 ~~R9515~~	WG22	"	14	16	15	25	0.2	0.5	35	85	120	80	6.3	4	*
✓ R9509	WG18	16.2 - 17.2	14	18	20	30	0.5	1.0	50	-	400	10	6.3	7½	*
⨍ ✓ MAG3 (2J42)	WG16	9.345 - 9.405	6.0	6.1	4.5	7.2	1.0	2.5	8	27	85	15	6.3	0.55	
			6.0	-	7.0	-	0.1	-	12	4.2	-	-			

* VH reduced to value specified on each tube within few seconds of application of anode voltage.

⨍ Frequency variants can be supplied over the range 9200 - 9600 Mc/s.

ϕ P.F: Pulling figure with 1.5:1 VSWR

(The Company reserve the right to make changes without prior notice.)

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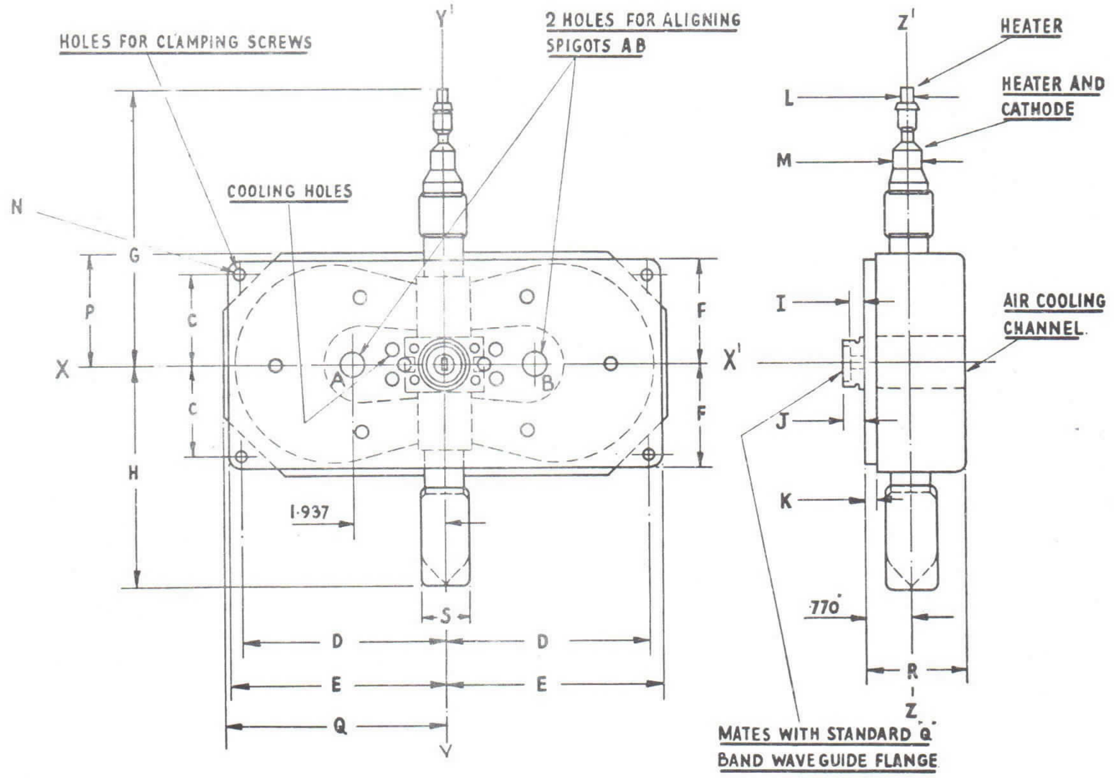
MAGNETRON TYPE R6138

DESCRIPTION

A fixed frequency packaged magnetron for pulsed operation at a wavelength of about 8.6 mm. with a peak power of about 18kW. (Prototype VX5027.) The cathode is indirectly heated.



TD

The valve is aligned by means of two aligning spigots fitting in holes "A" and "B"; .375" $^{+0.001''}_{-0.000''}$ diameter 3.874" ± .004" between centres.

The axis XX' is the line joining the centres of "A" and "B".

The axis YY' is perpendicular to XX' and 1.937" from the centre of A, and lies in the plane of the mounting surface.

The centre of the output coupler shall be within .002" of the intersection of XX' and YY'.

The heater terminal shall be within .050" of its nominal position w.r.t. the axis ZZ', where ZZ' is parallel to, and spaced .770" from YY' and lies in a plane spaced .770" from and parallel to, the mounting surface XY.

OTHER DIMENSIONS ARE

C: 1.687" ± .003"
D: 3.812" ± .003"
E: 4.065" max.
F: 1.940" max.
G: 5¼" max.
H: 5¼" max
I: .218" ± .005"
J: .400" ± .005"
K: .187" ± .002"
L: .250" ± .005" dia.
M: .540" ± .005" dia.
N: .213" ± .005" dia.
P: 2 1/16" max.
Q: 4 3/16" max.
R: 1 7/8" max.
S: 1" nominal

MECHANICAL DATA

See diagram.

Output

Waveguide coupler mates with a standard Inter-service Coupler WG22, No. Z830,019. A groove for a pressure seal is provided.

Mounting

Any orientation may be used.

The waveguide output is centred with respect to two spigot holes in the clamping plate (see drawing). The valve should be attached to the apparatus by four corner bolts in the holes indicated. Care should be taken that no stress is applied to the output coupler or to the cathode/heater terminal. Magnetic material must be spaced by more than 1¾″ from the valve, otherwise field strength will be reduced.

Weight

8¾ lb. 4 Kilogrammes.

Cooling

Forced air cooling of the anode and the cathode terminal is required (10 cu. ft./min.).

ELECTRICAL DATA

Connections

Anode (body). Grounded. Cathode/Heater, and Heater: special terminals. See diagram.

Rating

Cathode-Anode Voltage (Peak pulsed): 16.0kV max.

Heater Voltage V_H: 6.3V max.

Pulse duration: 0.5μsec. max., 0.05μsec. min.

Duration less than .05μsec. may be used, providing p.r.f. does not exceed 8,000/sec.

Cathode Current (mean): 4.5mA max.

Cathode Current (peak pulsed): 13.0A max., 6.0A min.

Below 6A efficiency drops off and bandwidth increases.

Heater Current I_H: 3.0A max. during warm-up 2.4A max. running.

Duty Cycle: 0.0004 max.

Wavelength 8.51 to 8.69 mm. (free space).
8.46 to 8.74 mm. (free space at end of life).

Power Output into matched load: Mean, 10W max. Peak 15kW min. at 10A peak input current.

Pulling Figure to VSWR of 1.5 varied over 360°. 45 Mc/s max. Spectrum must not split.

Pushing Figure at 10A peak cathode current: 4 Mc/s per Amp max.

Bandwidth between ½ power points for 0.2μsec. pulse: 20 Mc/s max.

Typical Operation

V_H: 6.3V for 2 minutes warming up period. As soon as cathode-anode voltage is applied, V_H must be reduced to a value 0, 0.5, 1.0, 1.5, 2.0, 3.0, 4.0 or 5.0V according to the figure on data sheet supplied with the valve. A relay energized by the mean cathode current is advised.

I_H: 2A.

Cathode Anode Voltage (peak pulsed): 13kV.

Cathode Current (peak pulsed): 10A. (mean): 4mA. (The dynamic impedance at the operating point is about 100 ohms; the modulator must therefore have the approximate characteristic of a constant current generator unless it is manually adjusted.)

Pulse duration: 0.2μsec. Pulse repetition rate: 2,000 pps.

Power output into matched load (Peak): 18kW. (Mean): 7W.

The safety factor of the window at normal input and output is about 2.5; overloading or operation into a VSWR greater than 1.5 will seriously reduce the factor.

Bandwidth (½ power): 10 Mc/s. Wavelength: 8.60 mm. Pulling Figure: 40 Mc/s. Pushing Figure: 2-3 Mc/s per A.

Life: 500-1,000 hours with peak cathode current not greater than 10A, and mean cathode current not greater than 4mA.

GENERAL NOTES

1. The cold resonance wavelength, measured with the valve body at normal operating temperature is 0.05 to 0.10 mm. below the generated wavelength. Loaded Q; Max, 400: Normal 230: Min. 150. Q_U is normally greater than Q_E. VSWR at cold resonance has an average value of 2, and a max. value of 4.

2. The packaging is suitable for storage of the valve. Valves should not be removed from the container until required for use. Closer stacking will result in interaction of the magnets, causing a permanent reduction in strength.

EMI Electronics Ltd Valve Division

HAYES MIDDLESEX ENGLAND (*Controlled by Electric and Musical Industries Ltd*)

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EMI

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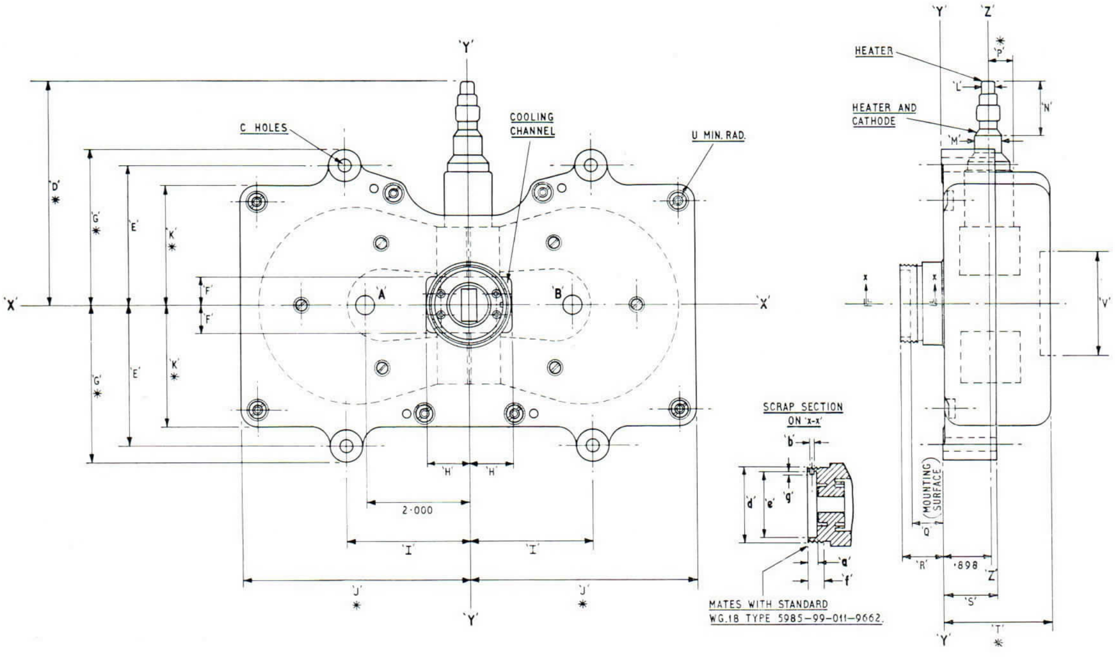
Serving Science and Industry

VALVE DIVISION

J-Band Magnetron Type R.9509 (VX5073)

A fixed frequency packaged magnetron for pulsed operation in J-band. This magnetron is conservatively rated and extremely robust, making it ideal for such applications as marine radar. Test valves have been operated to give three times the rated power output without deterioration.

Peak power output 50 kW.



Mechanical Data

DIMENSIONS (See diagram)

The axes XX and YY lie in the plane of the mounting surface.
The axis ZZ is parallel to and spaced 0.898″ from YY.
The axis of the heater terminal is within 0.050″ radius of ZZ.
The axis of the output coupler is within 0.006″ radius of the intersection of XX and YY.

A { Diameter 0.375″ ± 0.0005″
B { 4.000″ ± 0.005″ between centres
C : 0.265″ dia. min.
*D : 4.375″ max.
E : 2.687″ ± 0.005″
F : 17/32″ nom.
*G : 3⅛″ max.
H : 53/64″ nom.
I : 2.375″ ± 0.005″
*J : 4½″ max.
*K : 2½″ max.
L : 0.250″ ± 0.005″ dia.
M : 0.540″ ± 0.005″ dia.
N : 1″ ± ⅛″
*P : ⅝″ max. rad. from Z-Z

Q : 0.643″ ± 0.015′
R : 53/64″ nom.
S : 1.031″ ± 0.010″
*T : 2⅞″ max.
U : 9/32″ min. rad.
V : 2.000″ ± 0.010″ dia.
a : 0.180″ ± 0.002″
b : 0.099″ +0.000″ −0.001″ } dia.
d : 1½″ ODX28 TPI UNF BS 1580
e : 1.313″ +0.001″ −0.000″ } dia.
f : 19/64″ min. thread length
g : 0.042″ ± 0.005″

Dimensions marked * define the maximum envelope and relate to reference axes.

Output

Waveguide coupler mates with British Inter-Service coupler WG.18, No. 5985-99-011-9662.

Mounting

Any orientation may be used.

The two spigot holes are for alignment only and the valve must be supported at the four fixing holes, no stress being applied to the output coupler.

Magnetic material should be spaced at least 1½ inches from the magnetron.

Cooling

A forced air flow of about 15 cu ft/min should be directed through the channel provided. The cathode terminal needs a flow of some 5 cu ft/min.

Connections

See diagram.

Storage

The pack is suitable for storage of the tube which should not be removed from the container until required for use (see note on mounting).

Weight

10½ lb 4.8 Kg

Electrical Data

Ratings

		Max.	Typical	Min.
Pulse current	A	30	20	10
Mean current	mA	30	15	
Pulse length	μs	1.0	0.5	0.1
Pulse voltage rise rate	kV/μs	500	200	75
Pulse repetition frequency	c/s		1500	
Heater				
3 mins warm up		6.3V	7.5 A nom.	
Running at typical mean current		4V	5 A nom.	

Performance

		Max.	Typical	Min.
Peak power into matched load				
At 30A input current	kW		80	65
At 20A input current	kW		60	50
Mean power into matched load (0.5uS pulse, 1500 p.p.s)				
At 30A input current	W		60	50
At 20A input current	W		45	38
Pulse voltage (30A)	kV	16	15	
Pulse voltage (20A)	kV	14.5	14	
*Frequency	Gc/s	17.2	16.65	16.2
Pulling figure (1.5 VSWR, all phases)	Mc/s	20	10	
Pushing figure (20A)	Mc/s/A	2	1	
Bandwidth at 20A (¼-power points)	Mc/s	5	3	
Life under typical operating conditions	hrs			1000

TD

* Range over which current production is spread. Other frequencies can be made available by arrangement.

WARNING—The strong magnetic field from the tube is capable of causing damage to watches, &c.

EMI

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CD/1125/3M/961/BP.

Printed in Great Britain

E.M.I. ELECTRONICS LTD.

R9509 : Provisional Short Specification

Prototype : VX5073

The R9509 is a packaged, high power, pulsed magnetron for use at J-band. The design emphasizes robustness and conservative rating rather than minimum possible weight, making the valve particularly suitable for use in marine radar and other arduous conditions. Test valves have been operated at 300% of the rated power output without deterioration.

Performance

The standard input conditions are:-

Pulse voltage	Max	14.5 kV
Pulse current		20 A
Pulse length		0.5 Usec
Pulse repetition frequency		1500 c/s
Heater input (starting)		6.3 V 7.5 A
reduced when running to		4 V 5 A

With these input conditions the following output is obtained:-

Peak power into matched load	Min	50 kW
Mean power into matched load	Min	38 kW
Frequency	Max	17.2 kMc/s
	Min	16.2 kMc/s

(Present valves are within ±½% of 16.65 kMc/s: later valves will be spread over the full band.)

Pulling figure	Max	20 Mc/s

The waveguide output mates with the standard J-band (WG18) screwed ring coupler. No matching is necessary if the load V.S.W.R. is less than 1.5 and the peak power at standard input is not less than 30 kW at the worst phase of a 1.5 V.S.W.R.

A reduced voltage series of valves will shortly be available operating at 12 - 13 kV, with reduced output power.

Further details of the operation of the valve are contained in the Full Specification, available on request.

OCT. '58

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MAGNETRON 9551

Limitations, Precautions.

An input of 6A peak or 2mA mean current is apparently the maximum, this gives peak output around 4kW and mean powers around 1 watt. The maximum vane tip temperature is calculated at 200 - 300°C above the main body temperature at these inputs, for 1/5 µsec. pulses.

If sparking occurs when the valve is running at 4A or higher it is quite possible to melt the vane tips which will change the wavelength and eventually stop oscillation. This has been observed on two valves which ceased to give R.F. output though showing normal input characteristics (e.g. 2, 2 above). The solution to this is to have a current limiter either in the form of constant current output from the modulator or a physical impedance in series with the magnetron. Another method, which has been successfully adopted on the Ruislip ageing and test gears, is an H.T. cut-out actuated by peak currents above the running value.

It is possible, though unlikely, that an assymetrical jet of cooling air on the cathode insulator could cause enough decentering of the cathode to affect performance. Symmetrical cooling is an easily arranged precaution.

It is not known what rate of rise of pulse voltage or mismatch the valve will stand but 200kV/µsec. and 1.5:1 would seem reasonable maxima. The mismatch can easily be exceeded at O-band where small protrusions and irregularities in the guide give proportionally large reflections.

EC8/16
2.5.60.

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R6138
R9515.

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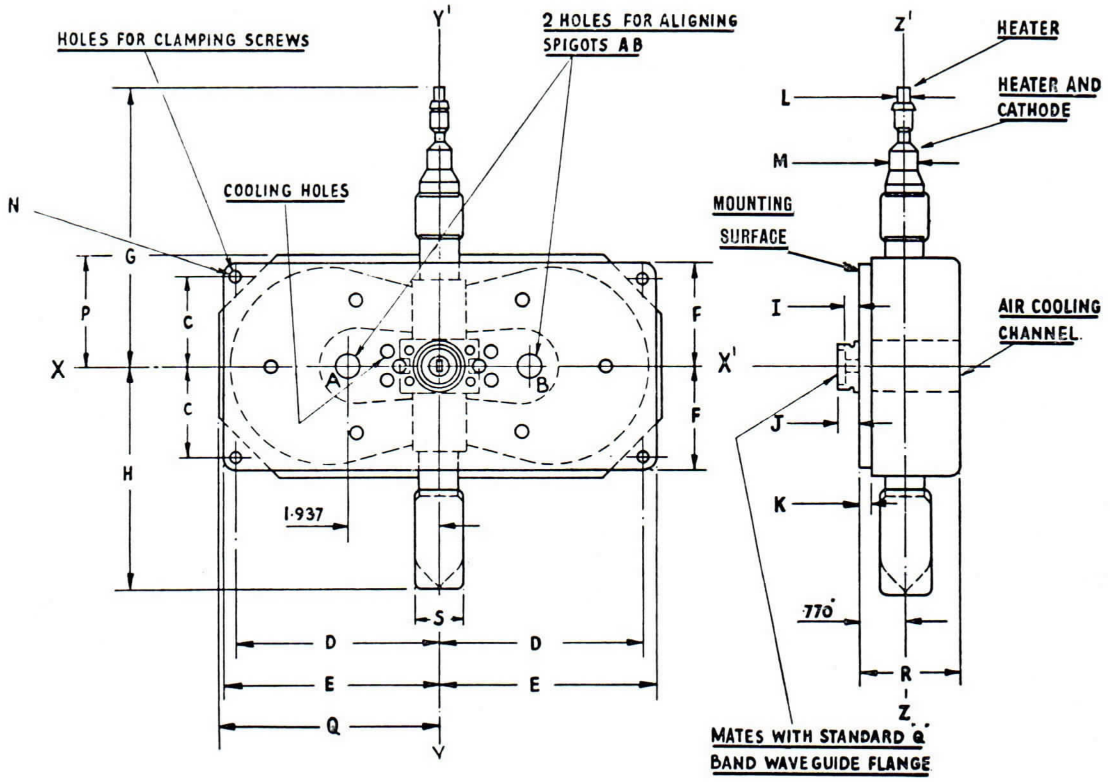
VALVE DIVISION

Q-Band Magnetrons

Description

Fixed frequency packaged magnetrons for pulsed operation at a wavelength of about 8.6 mm. Peak power output:—

Type R6138	15 kw.
Type R9515	35 kw.



TD

Mechanical Data

DIMENSIONS (See diagram)

The valve is aligned by means of two aligning spigots fitting in holes " A " and " B." Spigots should be $\frac{3}{16}$" long and tapered at the extreme ends.

The axis XX^1 is the line joining the centres of " A " and " B " and lies in the plane of the mounting surface.

The axis YY^1 is perpendicular to XX^1 and 1.937" from the centre of "A," and lies in the plane of the mounting surface.

The axis ZZ^1 is parallel to, and spaced .770" from YY^1.

Centre of heater terminal coincides with axis ZZ^1 to within .050".

A }	Diameter 0.375" + 0.001" − 0.000"		
B }	3.874" ± 0.004" between centres.		
C :	1.687" ± .003"	K :	.187" ± .002"
D :	3.812" ± .003"	L :	250" ± .005" dia.
E :	4.065" max.	M :	.540" ± .005" dia
F :	1.940" max.	N :	.213" ± .005" dia.
G :	5¼" max.	P :	2 $\frac{1}{16}$" max.
H :	5¼" max.	Q :	4 $\frac{3}{16}$" max.
I :	.218" ± .015"	R :	1⅞" max.
J :	13/32" nominal.	S :	1" nominal.

Output

Waveguide coupler mates with a standard Inter-service Coupler WG22, No. 5985-99-083-0018.

Mounting

Any orientation may be used.

The valve is aligned by the two spigot holes and must be supported at the four fixing holes. Care should be taken that no stress is applied to the output coupler or to the cathode/heater terminal. Magnetic material should be spaced at least 1⅜″ from the magnetron.

Weight

8¾ lb. 4 Kilogrammes.

Cooling

Forced air cooling of the anode and the cathode terminal is required. The body temperature should not be allowed to exceed 150° C.

Connections

See diagram.

Storage

The packaging is suitable for storage of the tube, which should not be removed from the container until required for use (See note on mounting).

Electrical Data

		R6138 (VX5027)			R9515 (VX5065)		
		Max.	Typical	Min.	Max.	Typical	Min.
Peak input current	A	13	10	6	25	15	10
Peak input voltage at 10A	kV	14	13	11.5	16	14	13
Mean input current	mA	5	4	—	8	6	—
Pulse length	μS	0.5	0.2	0.05	0.5	0.2	0.05
Pulse voltage rise rate	kV/μS	300	150	100	300	150	100
Wavelength	mm	8.69	8.60	8.51	8.69	8.60	8.51
Peak output power at 10A	kw	—	18.0	15.0	—	40	35
Pulling figure (1.5 VSWR, 10A)	Mc/s	45	40	—	100	75	—
Pushing figure (10A)	Mc/s/A	4	2	—	4	2	—
Bandwidth at 10A (0.2 μs pulse length)	Mc/s	20	10	—	20	10	—
Heating rating. Warm-up	2 minutes at	6.3 V 3.0 A			6.3 V 5.0 A		
Voltage reduced immediately upon application of H.T. to valve appropriate to mean current. If desired, the heater voltage may be controlled automatically by means of a series of relays.		Mean Current 1mA 2mA 3mA 4mA 5mA	Heater Voltage 5 V 4 V 3 V 2 V 1 V		Mean Current 3mA 4mA 5mA 6mA 7mA 8mA	Heater Voltage 4 V 4 V 3.5 V 3.5 V 3 V 3 V	
Life		500-1000 hrs. at 10A peak input 4mA mean			250-500 hrs. at 15A peak input 6mA mean		
Cold resonance		Wavelength 0.05-0.10 mm lower than generated wavelength QL 150-400 : QU > QE : VSWR at resonance ⩽ 4					
Mismatch		The load presented to the magnetron should have a VSWR ⩽ 1.5					

TD

WARNING—The strong magnetic field from the tube is capable of causing damage to watches, &c.

"Electrical Data" Erratum

For "Peak input voltage at 10A" - read -
"Peak input voltage at typical peak input current"
and similarly under :
"Peak output power at 10A"
"Pulling figure (1.5 VSWR, 10A)"
"Pushing figure (10A)" and Bandwidth at 10A"

l specifications without notice.

.lve Division

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ES8/1088/1000/261/BP.

Storage Tubes
&
Cathode Ray Tubes

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E.M.I. CATHODE RAY TUBES

This data-sheet briefly describes a range of cathode ray tubes manufactured to the highest standards of accuracy and reliability by E.M.I. for:-

RADAR, TELEVISION MONITORS

AND SPECIAL INSTRUMENTATION

EMI CATHODE RAY TUBE CHARACTERISTICS

RADAR TUBES

TYPE	AVAILABLE TO C.V. SPECIFICATION	V_h	I_h	SCREEN COLOUR	PHOSPHOR PERSISTENCE	MAX. DIA. (m.m.)	MAX. OVERALL LENGTH m.m.	FOCUS	DEFLECT	VA3 MAX. kv.	SENSITIVITY m.m./V/VA3		BASE
											X	Y	
MX 14	–	6.3	0.55	Orange	LP	17" Diag.	570	EM	EM	16	–	–	B12A
MX 18	CV487	4.0	1.0	Green	LP	254	442	EM	EM	9	–	–	B7B
MX 19	CV2472	4.0	1.0	Green with Orange Afterglow	LP	254	442	EM	EM	9	–	–	B7B
MX 20	CV429	6.3	0.6	Orange	LP	310	520	EM	EM	15	–	–	B12A
MX 21	CV1965	6.3	0.6	Orange	LP	310	487	EM	EM	15	–	–	B7B
MX 22	CV1952	6.3	0.6	Orange	LP	310	490	EM	EM	15	–	–	B7B
MX 23	CV2314	6.3	0.6	Blue with Yellow Afterglow	LP	310	520	EM	EM	15	–	–	B12A
MX 24	CV2388	6.3	0.5	Orange	LP	550	762	EM	EM	15.5	–	–	B12A
MX 25	CV2278	4.0	1.0	Orange	LP	230	437	EM	EM	5	–	–	B80
MX 26	VCRX415	6.3	0.55	Green	LP	127	355	ES	EM	8	–	–	B12A
MX 27	CV2469	6.3	0.6	Green	MP	127	355	ES	EM	13	–	–	B12A
MX 28	–	6.3	0.55	Green	MP	163	270	ES	EM	13	–	–	B12A
MX 31	CV2305	6.3	0.6	Red/Orange	LP	310	520	EM	EM	15	–	–	B12A
MX 33	CV2372	6.3	0.6	Orange	LP	234	477	EM	EM	15.5	–	–	B12A
MX 37	CV2415	4.0	1.0	Orange	LP	163	400	ES	EM	8	–	–	B80
MX 38	CV1530	4.0	1.0	Green	MP	163	400	ES	EM	8	–	–	B80

OSCILLOSCOPE TUBES

MX 2	CV418	4.0	1.2	Green	MP	90.5	383	ES	ES	2	620	530	B8E
MX 11	–	6.3	0.3	G86 Blue	SP	18.0	95	ES	ES	2.25	150	85	B7G
MX 13	–	6.3	0.5	Blue	SP	102	300	ES	ES	4	570	710	
MX 17	CV2222	4.0	1.2	Green	MP	90.5	383	ES	ES	4	620	530	B8E
MX 40	CV2352	6.3	0.3	Green	SP	67.5 x 158	419	ES	ES	6.0	925	1000	B14A

SPECIAL PURPOSE TUBES

MX 10	–	6.3	0.6	G86 Blue	SP	94.0	455	EM	EM	15	–	–	B7B
MX 12B	–	6.3	0.55	Blue	SP	254	440	EM	EM	10	–	–	B7B
MX 12W	–	6.3	0.55	White Flat Response	SP	254	440	EM	EM	10	–	–	B7B
MX 16	–	4.0	1.0	White, Green Blue, Yellow	SP	94	365	EM	EM	30	–	–	B7B
MX 29	–	4.0	1.0	Green	VS	162	495	EM	EM	25	–	–	B7B
MX 30	CV1738	4.0	1.0	Green	VS	162	495	EM	EM	25	–	–	B8G
MX 32	–	6.3	0.5	Blue	SP	94	340	EM	EM	28	–	–	B7B
MX 34	–												
MX 35	–												
MX 39	–	6.3	1.0	Blue	SP	70	305	ES	ES	4	140	–	B12G

MONITOR TUBES

MX 15	–	8.0	0.3	White	SP	14" Diag.	457	ES	EM	16	–	–	B12A
MX 41	–	4.0	1.0	White	SP	254	490	EM	EM	10	–	–	B7B
MX 43	–	6.3	0.55	White	SP	17" Diag.	533	ES	EM	16	–	–	B12A

N. B. ALL CATHODES ARE INDIRECTLY HEATED

LP: LONG PERSISTENCE – GREATER THAN 1 SEC.

MP: MEDIUM PERSISTENCE – 50mS to 1 SEC.

I.C. = INTERNALLY CONNECTED

out of date. See sheet 17-5-60

EMI CATHODE RAY TUBE CHARACTERISTICS

BRIEF DESCRIPTION	PIN CONNECTIONS																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	SC	SC	SC	SC
Radar tube for aircraft control	H	M	–	–	–	–	–	–	–	A_1	C	H	–	–	–	A_2	–	–	–
Airborne radar tube	I.C.	A_1	M	I.C.	H	C	H	–	–	–	–	–	–	–	–	A_2	–	–	–
" " "	I.C.	A_1	M	I.C.	H	C	H	–	–	–	–	–	–	–	–	A_2	–	–	–
P.P.I type	H	M	–	–	–	N.C.	N.C.	–	–	A_1	C	H	–	–	–	A_2	–	–	–
" " high resolution	I.C.	A_1	M	I.C.	H	C	H	–	–	–	–	–	–	–	–	A_2	–	–	–
Flat face	I.C.	A_1	M	I.C.	H_2	C	H	–	–	–	–	–	–	–	–	A_2	–	–	–
Double screen	H	M	–	–	–	N.C.	N.C.	–	–	A_1	C	H	–	–	–	A_2	–	–	–
Metal cone	H	M	–	–	–	–	–	–	–	A_1	C	H	–	–	–	–	–	–	–
Flat screen dia. 204 m.m.	–	H	–	–	M	–	H	C	–	–	–	–	–	–	–	A_2	–	–	–
Airborne	H	M	–	–	–	A_2	–	–	–	–	C	H	–	–	–	A_2	–	–	–
Low flicker level	H	M	–	–	–	A_3	I.C.	–	–	A_1	C	H	–	–	–	A_4	–	–	–
" " "	H	M	–	–	–	A_2	A_1	–	–	–	C	H	–	–	–	A_3	–	–	–
Short persistence tail	H	M	–	–	–	N.C.	N.C.	–	–	A_1	C	H	–	–	–	A_2	–	–	–
Precision type	H	M	–	–	–	N.C.	N.C.	–	–	N.C.	C	H	–	–	–	A_2	–	–	–
P.P.I.	–	A_1	A_2	–	M	C	H	H	–	–	–	–	–	–	–	A_3	–	–	–
P.P.I.	–	A_1	A_2	–	M	C	H	H	–	–	–	–	–	–	–	A_3	–	–	–

	A_2	H	C	H	M	X_2	A_3	X_1	–	–	–	–	–	–	–	Y_1	Y_2	–	–
Miniature tube	A_3	X_1	A_2	Y_1	H+C	H	M	–	–	–	–	–	–	–	–	–	–	–	–
Double gun dis. tube	C_A	H_A	A_2B	A_2A	A_1	Y_1A	Y_2A	A_3	Y_1B	Y_2B	H_B	H_{A+B}	Mod B	C_B	M_A	X_1A	X_1B	X_2A	X_2B
	A_2	H	C	H	M	X_2	A_3	X_1	–	–	–	–	Y_1	Y_2	–	–	–	–	–
Rectangular face	H	C	M	A_2	–	–	Y_1	Y_2	A_3	X_2	X_1	–	A_1	H	–	–	–	–	–

High resolution tube	I.C.	I.C.	M	I.C.	H	C	H	–	–	–	–	–	–	–	–	A	–	–	–
Photographic screen	A_2	A_1	M	H	H	C	I.C.	–	–	–	–	–	–	–	–	A_3	–	–	–
" "	A_2	A_1	M	H	H	C	I.C.	–	–	–	–	–	–	–	–	A_3	–	–	–
Projection tube	I.C.	I.C.	M	I.C.	H	C	H	–	–	–	–	–	–	–	–	A	–	–	–
Film scanner	I.C.	I.C.	M	I.C.	H	C	H	–	–	–	–	–	–	–	–	A	–	–	–
Low slope tube	I.C.	H	I.C.	I.C.	M	I.C.	H	C	–	–	–	–	–	–	–	A	–	–	–
Protection tube	H	M	I.C.	H	C	I.C.	–	–	–	–	–	–	–	–	–	A	–	–	–
6Digit tube An encoding tube for pulse code modulation systems	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6Digit tube A decoding tube for pulse code modulation systems	Target Heater	– Heater	– Support	– Grid	Target A_1	Target Support	Gauze –	Target Cathode	Target Support	– A_1	Box A_2	Target Support	–	–	–	–	–	–	–
Ribbon beam tube	H	M	A_3	A_4	I.C.	Y_1	I.C.	A_1	Y_1	I.C.	C	H	–	–	–	–	–	–	–

	H	M	–	–	–	A_3	N.C.	–	–	A_1	C	H	–	–	–	A_4	–	–	–
	I.C.	A_1	M	I.C.	H	C	H	–	–	–	–	–	–	–	–	A_2	–	–	–
	H	M	–	–	–	A_3	N.C.	–	–	A_1	C	H	–	–	–	A_4	–	–	–

SP: SHORT PERSISTENCE – 10μS to 50mS

VS: VERY SHORT PERSISTENCE – LESS THAN 10μS

N.C. = NO CONNECTION

VALVE DIVISION'S PRODUCTS INCLUDE:-

PHOTOMULTIPLIER TUBES MAGNETRONS KLYSTRONS

CAVITIES TELEVISION CAMERA TUBES STORAGE TUBES

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CATHODE RAY TUBES

RADAR TYPES

✓ MX 14	Rectangular 17" diagonal, fluoride screen. 16KV.
✓ MX 18	CV.487
MX 19	10" screen with special afterglow characteristics. 9KV.
✓ MX 20	CV.429
✓ MX 21	12" Fluoride screen (CV.1965). 15KV.
✓ MX 22	CV.1952
✓ MX 23	12" double layer screen (CV 2314)
✓ MX 24	21" Fluoride screen. 15.5KV
MX 25	CV.2278
MX 26	VCRX.415
✓ MX 27	5" ES focus, EM defl. 13KV. Willemite screen but available with other phosphors.
MX 28	6" High brightness E.S. focus
MX 31	Similar to MX 21, but shorter afterglow.
✓ MX 33 – MX32	9" almost flat face. Fluoride screen (CV 2372) projection tube
✓ MX 37	6" ES focus, EM defl. Fluoride screen (CV 2415)
✓ MX 38	MX 37 with C screen (single layer sulphide.) (CV 1530)
✓ MX 32	VX.5074. Very high brightness ~~projective~~ projection tube.
✓ MX 42	9" ES MX.33

OSCILLOSCOPE TUBES

✓ MX 2	$3\frac{1}{2}$", 2KV., two side arms.
✓ MX 11	High quality miniature tube, 0.7" dia., 2KV. Suitable for stacking.
✓ MX 13	Inclined double gun tube.
✓ MX 17	Improved MX 2, 4KV.
MX 40	Rectangular, 6" x 2". 6KV.
✓ MX 46	High speed tube. Helical P.D.A.
MX 47	6" double gun

SPECIAL TYPES

MX 10	3" flat face, high definition radar recording tube
MX 12	Blue and White LogEtronics
✓ MX 16	Colour projection tube
✓ MX 29	R.5161. Flying spot film scanner, very short afterglow 23KV.
✓ MX 29S	Similar to MX 29 but with better overall focus. The focus at the centre of the tube is slightly inferior to the MX.29.
✓ MX 30	Similar to MX 29 (CV 1738) with low slope characteristic.
✓ MX 34	6 digit encoding tube } To special order only.
✓ MX 35	Decoding tube }
✓ MX 39	Ribbon beam recording tube
✓ MX 45	6" high resolution.
MX 48	Barrier Grid Storage Tube

Under Development:	TDX 1	2" high resolution
	TDX 2	9" high resolution
	TDX 3	I.R. Source.

MONITORS

MX 15	14" diagonal rectangular. 16KV.
✓ MX 41	10". round monitor 7KV.
MX 43	17" diagonal rectangular. 16KV.
MX 44	15" round monitor 7KV.

17/5/60.

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LIST OF CATHODE RAY TUBES
AVAILABLE TO CV SPECIFICATIONS

*	CV 418	3½" Electrostatic oscilloscope tube
*	CV 429	12" Radar tube - magnetic deflection and focussing
*	CV 487	10" Radar tube - magnetic deflection and focussing medium persistence screen
*	CV 1530	6" tube - electrostatic focussing, magnetic deflection
*	CV 1738	6" flat faced tube - ultra-short persistence screen for film scanning
*	CV 1952	12" flat screen radar tube, magnetic deflection and focussing
*	CV 1965	12" high definition radar tube, magnetic deflection and focussing
*	CV 2222	3½" Electrostatic oscilloscope tube, having higher working voltage than CV418
	CV 2278	9" Radar tube, magnetic deflection and focussing
*	CV 2305	12" Radar tube, magnetic deflection and focussing, medium persistence screen
*	CV 2388	21" Radar tube, magnetic deflection and focussing
*	CV 2415	As CV 1530, but long persistence screen
*	VCRX 352	9" tube for radar - magnetic deflection and focussing
*	VCRX 407	5" tube - electrostatic focussing, magnetic deflection, medium to short persistence screen
*	VCRX 415	As VCRX 407 but long persistence screen
	VCRX 419	6" x 2" A-Scan tube - electrostatic focussing and deflection
*	TA 10/B	CV 487 - blue screen for photographic purposes
*	TA 10/C	Higher performance version of CV 487 - long persistence screen

* Readily available

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MX.2 (CV418)

The MX.2 is a 3½" electrostatically focused, electrostatically deflected CRT with a green medium persistence phosphor.

CHARACTERISTICS

Mechanical

Overall length	15 in. max	380 mm
Neck diameter	2⅛ in. max	53 mm
Face diameter	3½ in. max	89 mm
Useful screen diameter	2¾ in. min	70 mm

Phosphor Green medium afterglow

Electrical	Max	Typical	Min.
Heater voltage		4V	
Heater current	1.32A	1.2A	1.08A
Final Anode Voltage VA3 A1 Internally connected to A3	2KV	1.2KV	
Second Anode Voltage VA2 for focus at VA3 = 1.2KV	175V	150V	125V
Grid voltage for cut-off at VA3 = 1.2KV	-50V	-40V	-25V
Line width at 20μA beam current	1 mm	0.7 mm	
Deflection Plate Sensitivities			
X plates	700mm/V VA3	620mm/V VA3	540mm/V VA3
Y plates	600mm/V VA3	530mm/V VA3	460mm/V VA3
Deviation of undeflected spot from centre of screen	10 mm		
Capacitances X1/all	15pF	12pF	
X2/all	15pF	12pF	
Y1/all	10pF	8pF	
Y2/all	10pF	8pF	
G /all	15pF	10pF	

Base EM8 Side Contacts Y1 & Y2

Pin Connections	1	2	3	4	5	6	7	8
	A2	H	C	H	G	X2	A3	X1

EC8/69

11.5.61.

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MINIATURE OSCILLOSCOPE TUBE TYPE MX11

The MX11 oscilloscope tube is a high quality, compact tube which has been designed to facilitate easy stacking in confined spaces. The tube has no side arms, is pinch pumped and plugs into a standard B7G socket. The screen is a blue short persistence phosphor suitable for photographic recording and by suitable arrangements of batteries of tubes it is possible to obtain instantaneous, simultaneous monitoring of several waveforms.

Electrostatic focus	Diameter 0.7 inch
Electrostatic deflection	Overall length 3¾ inch

Rating & Operating Conditions	Unit	Max.	Typical	Min
Heater voltage AC	Volts		6.3V	
Heater current	Amps	0.35	0.33	0.3
Cathode voltage	Volts		0	
Final anode voltage	Volts	2200	2000	
Focus voltage at final anode voltage 2KV	Volts	300	270	250
Cut off " " " " " "	Volts	-65	-40	-25
Beam current	μA		50	
X_1 Plate Voltage			2000 ± 150V	
Y_1 Plate Voltage			2000 ± 100V	

Deflection

Both pairs of deflecting plates operate asymmetrically. One of each pair of plates is connected internally to the final anode.

Spot Size		mm	0.4	0.35	0.3
Deflection sensitivity	Y Plate:	mm/V VA_3	170	150	130
	X Plate:	mm/V VA_3	95	85	75

Pin Connections: Base B7G

Pin	Connection
1	Final anode (A_1, A_3, A_4, X_2, Y_2.)
2	X_1 Plate
3	Focus A_2
4	Y_1 Plate
5	Heater & Cathode
6	Heater
7	Modulator

EC8/45R
19.10.60.

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OSCILLOSCOPE TUBE TYPE MX.13

The MX.13 is a double gun, 4" faced, electrostatically focussed, electrostatically deflected Cathode Ray Tube with a blue, short persistence fluorescent screen.

The two guns are inclined towards each other, so that the undeflected spots are in the centre of the tube face.

CHARACTERISTICS

Mechanical

Overall length	$11\frac{3}{4}$" maximum
Neck diameter	2.95"
Overall diameter	4"
Useful screen dimensions	3-1/16" in X direction 2-1/16" in Y direction

Electrical	Unit	Max.	Typical	Min.
Heater Volts	Volts		6.3	
Heater Current	Amps.	0.6	0.5	0.45
Final Anode Voltage	K.Vlts.	5.0	4.0	
A_1 Voltage	K.Vlts.	2.5	2.0	
A2 Focus Voltage	Volts	500	450	400
Mod. volts for cut-off	Volts	-75	-50	-30
Spot size at a light intensity of 0.06 cdls.	mm.	0.4		
Y Plate Deflector Sens	mm/v.	$760/VA_3$	$710/VA_3$	$660/VA_3$
X Plate Deflector Sens.	mm/v.	$620/VA_3$	$570/VA_3$	$520/VA_3$

Capacitances.

Each X Plate to all other electrodes	p.f.	12
Each Y Plate " " " " "	p.f.	12
Modulator " " " " "	p.f.	12
Cathode " " " " "	p.f.	9

... See over

Oscilloscope Tube
Type MX13.

Pin Connections

Guns A. & B.

Pin	Electrode
1	Cathode A
2	Heater A
3	A_2 Focus B
4	A_2 Focus A
5	A_1 A & B
6	Y_1 A
7	Y_2 A
8	A_3 A & B
9	Y_1 B
10	Y_2 B
11	Heater B
12	Heater A & B
13	Modulator B
14	Cathode B
15	Modulator A
Four Side Contacts	X_1A, X_2A, X_1B, X_2B.

Base : 15 pin

EC8/1 - 14.3.60.

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CATHODE RAY TUBE TYPE MX14

The MX14 is a magnetically focused, magnetically deflected rectangular C.R.T. with a long afterglow fluorescent screen, intended for radar display applications.

The fluoride phosphor type OOL65 has an aluminium backing to give maximum light output.

CHARACTERISTICS

Mechanical (see fig. overleaf.)

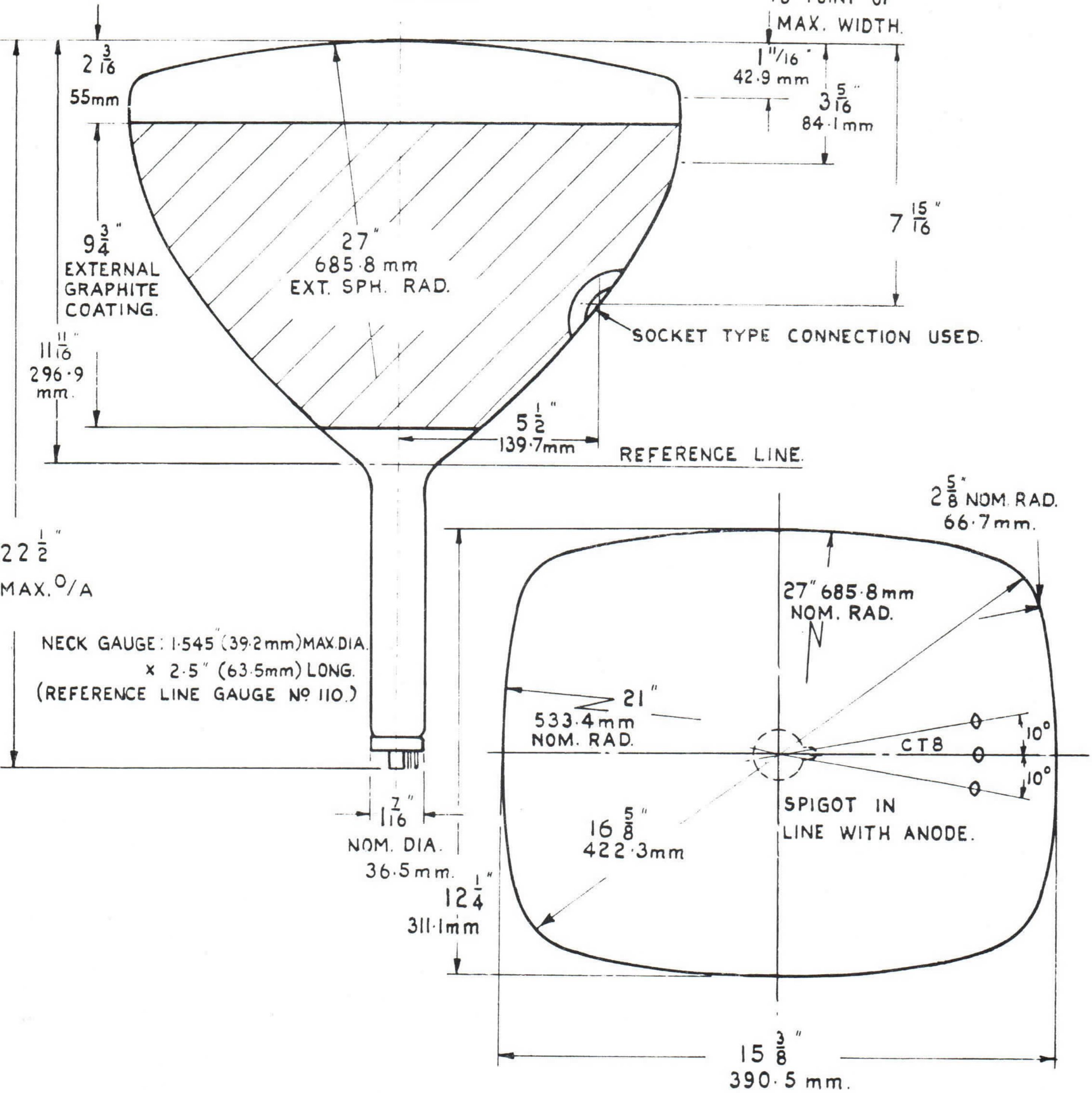
Overall length	22½" max.	Spacing cathode-screen.	19"
Neck diameter.	$1.\frac{7}{16}$".	Diagonal of bulb.	17"
		Deflection angle	70°.

Electrical		Max.	Typical.	Min.
Heater Voltage	Volts.	6.8	6.3	5.8
Heater Current	Amperes		0.5	
A2 voltage	Kilovolts.	17	15	
A1 "	Volts.	750	600	
*Modulator voltage for cutoff	Volts.	-60	-45	-30
Beam current	Microamperes	50		
*A1 current	"	10		
*Spot diameter, (with specified coils)	mm.	0.3		
Deviation of unfocused spot from centre of screen.	mm.	12		
Capacitances. Modulator to all electrodes.	pf.	15		
Cathode to all electrodes.	pf.	15		

*V_{A1} 600V. V_{A2} 15kV. V_H 6.3V. I_B 0 to 50 μA

To prevent damage to the screen material and to ensure that maximum life is obtained, the tube should not be operated with a stationary or slowly moving spot of high mean current density. The beam current should not exceed 50 μA, while for maximum cathode life the heater voltage should be controlled as closely as possible to 6.0V.

MX 14.



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BASE CONNECTIONS. (DUODECAL BASE). A2 SIDE CONTACT.

PIN No.	1	2	3	4	5	6	7	8	9	10	11	12
ELECTRODE	H	M	NO PINS			BLANK		NO PIN		A1	C	H

H – HEATER. M – MODULATOR. C – CATHODE.

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Tube Type MX.16

The MX.16 is a magnetically focused, magnetically deflected C.R.T., available with red, blue or green phosphors, intended for colour projection T.V. receivers.

Three different radii of curvature are available for the face plate, to enable the tube to be used in projection systems with different physical dimensions.

The phosphor is aluminium backed, to give maximum light output, and the front face is of special, blemish-free, non-solarising glass.

CHARACTERISTICS

Phosphors	Peak Wave Length	Afterglow 1/10th of initial value
Red	5850 Å	40 m.sec.
Green	5150 Å	40 m.sec.
Blue	4200 Å	5 m.sec.

Electrical	Maximum	Typical	Minimum
Heater Voltage	6.8V	6.3V	5.8V
Heater Current		0.5A	
Anode Voltage	30kV	28kV	
Grid Voltage for C.O.	115V	85V	55V
Beam Current		1 mA	
Line Width at 500 μA	0.25mm	0.2mm	
Deviation of unfocused spot from centre of face	5mm		
Capacitances Grid/all	15pf		
Cath/all	10pf		

Base - B7B

/Over ....

Pin Connections

Pin	Electrode
1	H_1
2	N.C
3	G
4	H_1
5	H_2
6	C
7	H_1
CT8 Side Contact	Anode

Mechanical	Type A	Type B	Type C
Overall Length Max.	14½" 370mm	14½" 370mm	14½" 370mm
Neck Diameter Nominal	1.38" 35mm	1.38" 35mm	1.38" 35mm
Useful Screen dia. Min.	3.2" 84mm	3.2" 84mm	3.2" 84mm
Overall Dia. Max.	3.65" 93mm	3.65" 93mm	3.65" 93mm
Radius of curvature of face plate	7.6" 193mm	5.62" 143mm	6.36" 162mm
Deflection Angle	40°	40°	40°
Front Face Glass Thickness	0.180" 4.5mm	0.148" 3.75mm	0.180" 4.5mm

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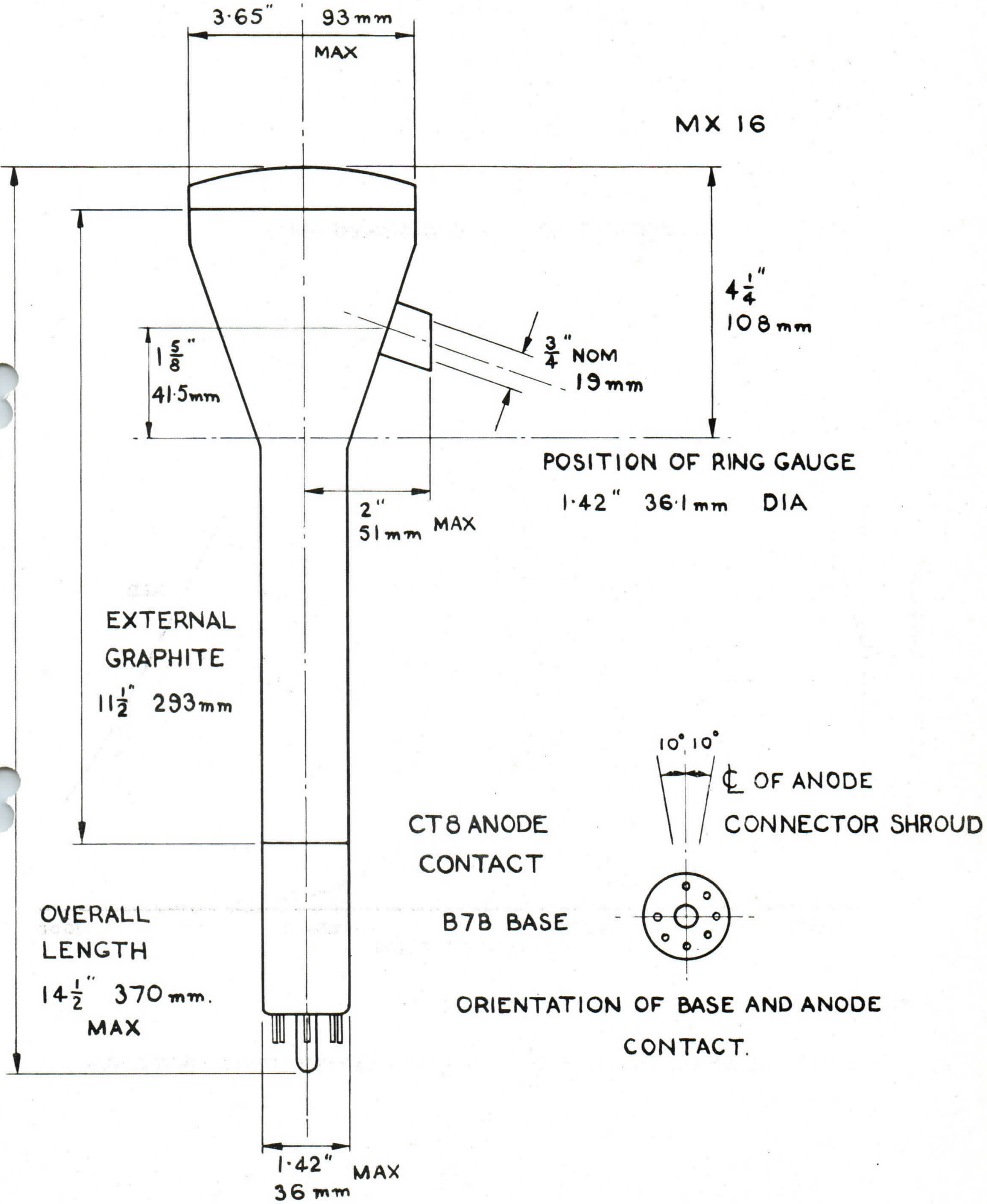
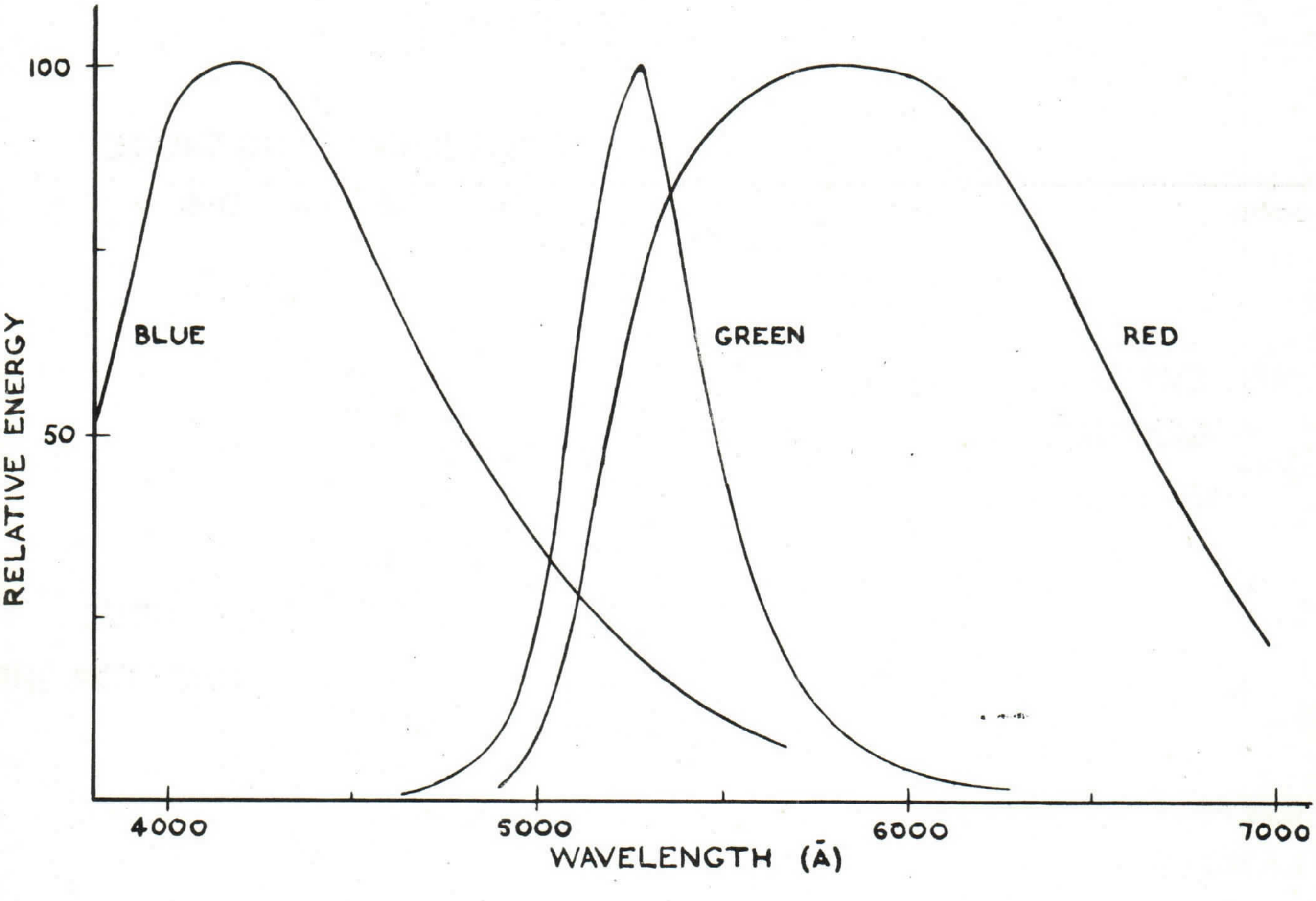
MX 16



ORIENTATION OF BASE AND ANODE CONTACT.

PROJECTION TUBE WHITE COMPONENTS



SPECTRAL EMISSION CHARACTERISTICS OF LUMINESCENT MATERIALS.

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MX.17 (CV.2222)

The MX.17 is a 3½" electrostatically focused, electrostatically deflected C.R.T. with a green medium persistence phosphor.

Characteristics

Mechanical

Overall length	15" max	380 mm
Neck diameter	2⅛" max	53 mm
Face diameter	3½" max	89 mm
Useful screen diameter	2¾" min	70 mm

Phosphor Green - medium persistence

Electrical

	Max	Typical	Min
Heater voltage		4 volts	
Heater current	1.32A	1.2A	1.08A
Final Anode Voltage VA_3 A_1 internally connected to A_3	4kV	3.5kV	
Second anode Voltage VA_2 for focus at VA_3 = 3.5kV	525V	450V	350V
Grid voltage for cut-off at VA_3 = 3.5kV	-60V	-45V	-30V
Line width at 20 µA beam current	0.8mm	0.6mm	
Deflection plate sensitivities			
X Plates	$\frac{700}{VA_3}$ mm/V	$\frac{620}{VA_3}$ mm/V	$\frac{540}{VA_3}$ mm/V
Y Plates	$\frac{600}{VA_3}$ mm/V	$\frac{530}{VA_3}$ mm/V	$\frac{460}{VA_3}$ mm/V
Deviation of undeflected spot from centre of screen	10 mm		
Capacitances X_1/all	15pF	12pF	
X_2/all	15pF	12pF	
Y_1/all	10pF	8pF	
Y_2/all	10pF	8pF	
Grid /all	15pF	10pF	
Base	EM8		

Pin connections:	1	2	3	4	5	6	7	8	Side Contacts
	A_2	H	C	H	G	X_2	A_3	X_1	Y_1 and Y_2

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EMI CATHODE RAY TUBE TYPE MX.18 (CV487)

The MX.18 is a 10 in magnetically focused magnetically deflected CRT with a green medium persistence phosphor.

CHARACTERISTICS

Mechanical

Overall length	17.4 in max.	442 mm max
Neck diameter	1.42 in	36 mm
Face diameter	$10\frac{1}{8}$ in	257 mm max
Useful screen diameter	$8\frac{7}{8}$ in min.	225 mm min
Deflection Angle	50^0	

Phosphor Green medium afterglow aluminium backed

Persistance to $\frac{1}{100}$ th of initial value = 4 sec.

Electrical

	Max	Typical	Min
Heater voltage		4V	
Heater current	1.1A	1.0A	0.84A
Final Anode Voltage VA2	7KV	5.5KV	
1st Anode Voltage VA1	300V	250V	
Grid voltage for cut-off at VA1 = 250V	-60V	-40V	-25V
Line width at 50 μA beam current	0.5 mm	0.4 mm	
Deviation of unfocused spot from centre of screen	10 mm		
Capacitances			
G/all	15pF		
C/all	10pF		

Base B7B

Pin connections	1	2	3	4	5	6	7
	IC	A1	G	IC	H	C	H

TD

EC8/C/118
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DS.130

TD

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VALVE DIVISION

MX.20 (CV.429)

The MX.20 is a 12", magnetically focussed, magnetically deflected Cathode Ray Tube with an orange, long afterglow phosphor, intended for use in P.P.I. Radar Displays.

Characteristics

MECHANICAL	Inches.	Millimeters.
Overall length	20.5 max.	520 max.
Neck diameter	1.38	36
Face diameter	12.2 max.	310 max.
Useful screen diameter	10 min.	250 min.
Deflection angle	50°	

Phosphor - Orange - aluminium backed.
Persistence to 1/100th of initial value - 120 secs.

ELECTRICAL	Max.	Typical.	Min.
Heater Voltage		6.3 V	
Heater current	0.6A	0.55A	0.5A
Final anode A_2 voltage	15kV	15kV	
First anode A_1 voltage	600V	300V	
Grid voltage for cut-off at VA_1 = 300V	-90V	-60V	-30V
Line width at 50 µA beam current.	0.4mm.	0.35mm.	
Deviation of unfocussed spot from centre of screen.	15mm.		

Capacitances

Grid/all	12 p.f.
Cathode/all	12 p.f.

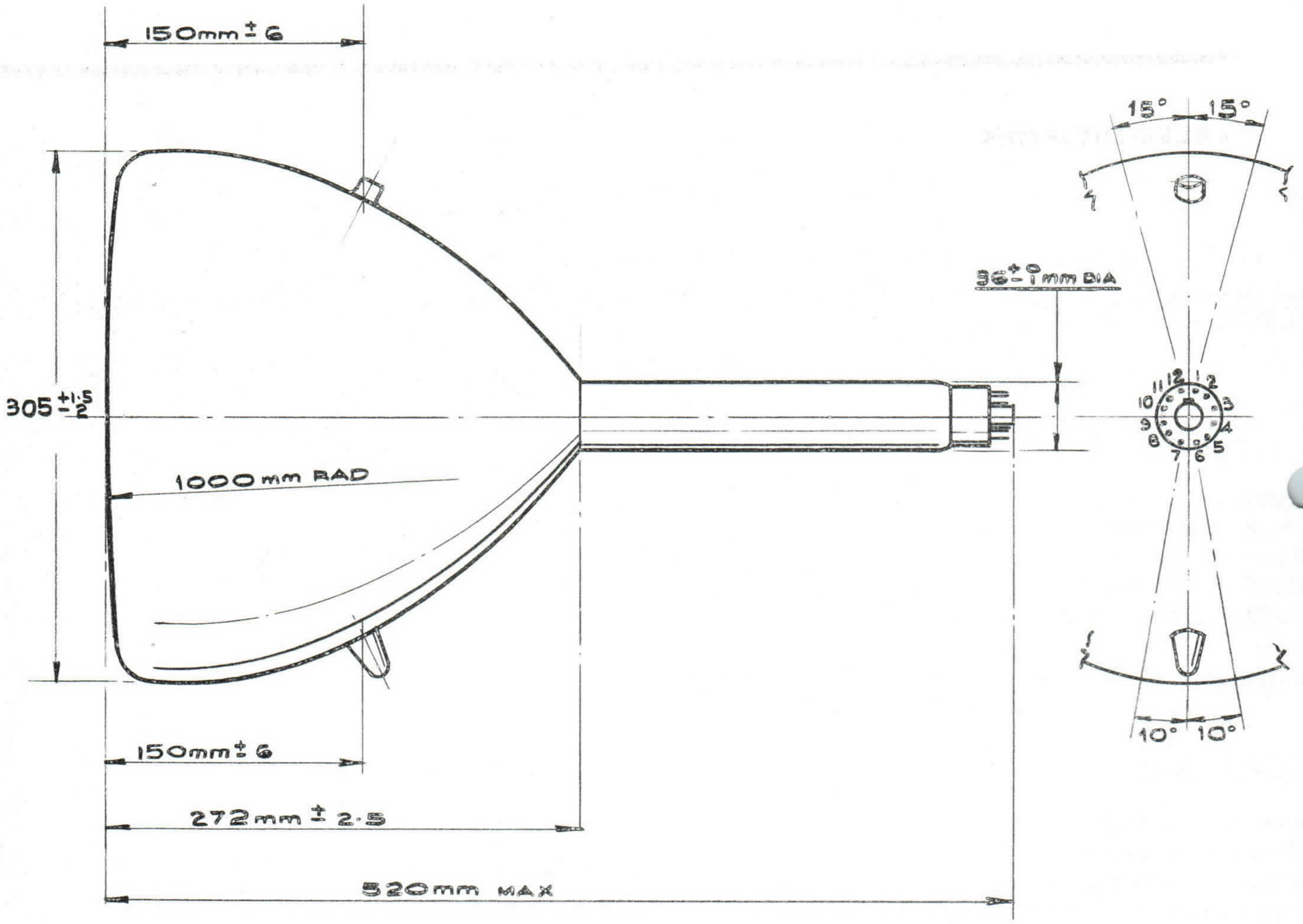
BASE - - B12A

Pin Connections:

1	2	3	4	5	6	7	8	9	10	11	12	Side Ct.
H	G	-	-	-	N.C.	N.C.	-	-	A1	C	H	A_2

To prevent damage to the screen material, the tube should not be operated with a stationary or slowly moving spot of high current density. The tube should be operated at its minimum useful brightness, i.e. maximum beam current 50 µA.

MX 20



EC8/32
14.9.60.

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MX.21 (CV.1965)

The MX.21 is a 12" magnetically focussed, magnetically deflected Cathode Ray Tube with an orange, long afterglow phosphor, intended for use in high resolution P.P.I. Radar Displays.

Characteristics

MECHANICAL	Inches.	Millimeters.
Overall length	19 max.	487 max.
Neck diameter	1.38	36
Face diameter	12.2 max.	310 max.
Useful screen diameter	10 min.	250 min.
Deflection angle	50°	

Phosphor - Orange - aluminium backed.
Persistence to 1/100th initial value - 60 secs.

ELECTRICAL	Max.	Typical.	Min.
Heater voltage		6.3 V	
Heater current	0.6A	0.55A	0.5A
Final anode A_2 voltage	15kV	15kV	
First anode A_1 voltage	600V	600V	
Grid voltage for cut-off at VA_1 = 600V	-60V	-45V	-25V
Line width at 50 μA beam current	0.3mm.	0.25mm.	
Deviation of unfocussed spot from geometric centre of screen	12mm.		

Capacitances

Grid/all	15 p.f.
Cathode/all	15 p.f.

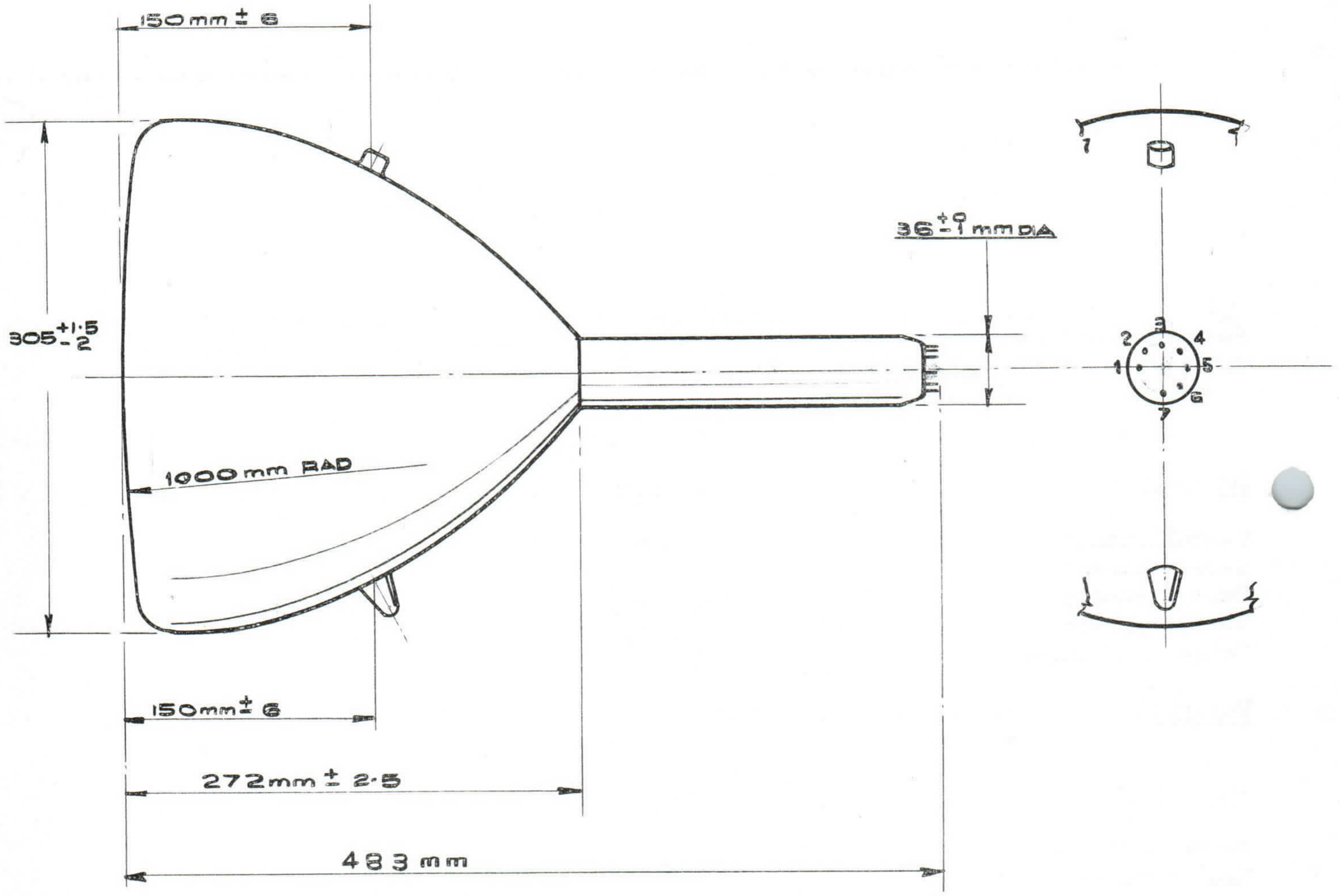
BASE - - B7B

Pin connections:

1	2	3	4	5	6	7	Side Contact
I.C.	A1	G	I.C.	H	C	H	A_2

To prevent damage to the screen material, the tube should not be operated with a stationary or slowly moving spot of high current density. The tube should be operated at its minimum useful brightness, i.e. max. beam current 50 μA.

MX 21



EC8/33
14.9.60.

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MX.22 (CV.1952)

The MX.22 is a flat-faced, 12", magnetically focussed, magnetically deflected Cathode Ray Tube with an orange, long afterglow phosphor, intended for use in P.P.I. Radar Displays.

Characteristics

MECHANICAL	Inches.	Millimeters.
Overall length	19 max.	490 max.
Neck diameter	1.38	36
Face diameter	12 max.	307 max.
Useful screen diameter	10 min.	250 min.
Deflection angle	50°	

Phosphor - Orange - aluminium backed.
Persistence to 1/100th initial value - 60 secs.

ELECTRICAL	Max.	Typical.	Min.
Heater voltage		6.3 volts	
Heater current	0.6 A	0.55 A	0.5 A
Final anode A_2 voltage	15kV	15kV	
First anode A_1 voltage	600 Volts	300 Volts	
Grid voltage for cut-off at VA_1 = 300 volts	-60 volts	-45 volts	-20 volts
Line width at 50 µA beam current	0.8 mm.	0.6 mm.	
Deviation of unfocussed spot from centre of screen	15 mm.		

Capacitances

Grid/all	15 p.f.
Cathode/all	8 p.f.

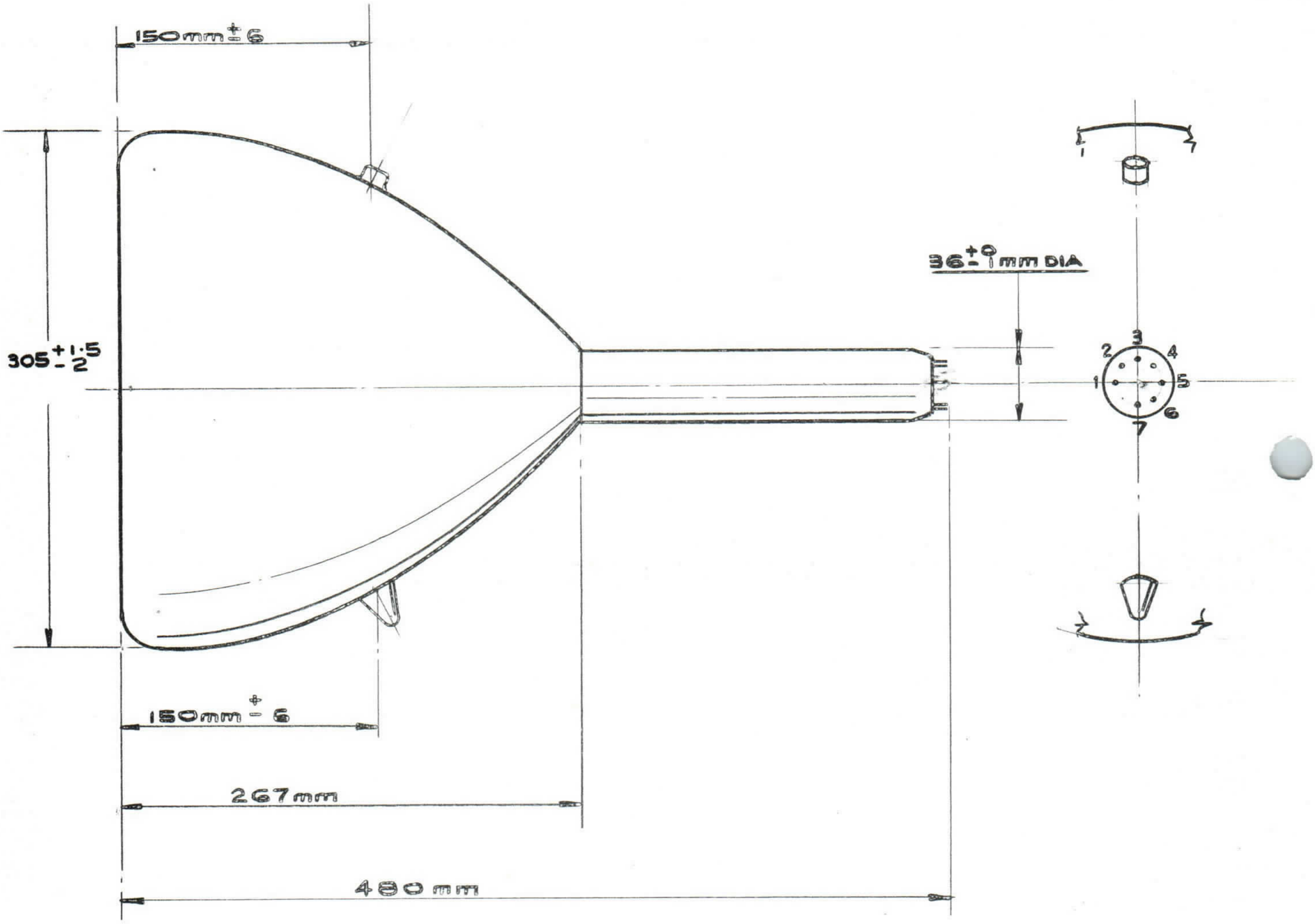
BASE - - B7B

Pin connections:

1	2	3	4	5	6	7	Side Ct.
I.C.	A1	G	I.C.	H	C	H	A_2

To prevent damage to the screen material, the tube should not be operated with a stationary or slowly moving spot of high current density. The tube should be operated at its minimum useful brightness, i.e. max. beam current 50 µA.

MX 22



EC8/34.
14.9.60.

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VALVE DIVISION

MX.23 (CV2314)

The MX.23 is a 12", magnetically focused, magnetically deflected C.R.T. with a blue flash, yellow afterglow phosphor, intended for use in P.P.I. Radar Displays.

Characteristics

Mechanical

Overall length	20.5" max	520mm max
Neck diameter	1.38"	36mm
Face diameter	12.2" max	310mm max
Useful screen diameter	10"	250mm **min**
Deflection angle	50°	

Phosphor

Blue flash - yellow afterglow - aluminium backed. Persistence to 1/100th of initial value - 12 secs.

Electrical

	Max	Typical	Min
Heater voltage		6.3V	
Heater current	0.6A	0.55A	0.5A
Final anode A_2 voltage	600V	300V	
Grid voltage for c.o. at VA1 = 300 volts	-90V	-60V	-30V
Line width at 50 µA beam current	0.4mm	0.35mm	
Deviation of unfocused spot from centre of screen	15mm		
Capacitance			
G/all	12pF		
C/all	12pF		
Base	B12A		

Pin Connections:	1	2	3	4	5	6	7	8	9	10	11	12
	H	G	-	-	-	NC.	NC.	-	-	A_1	C	H

Side Contact A2

To prevent damage to the screen material, the tube should not be operated with a stationary or slowly moving spot of high current density. The tube should be operated at its minimum useful brightness, i.e. maximum beam current 50 µA.

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CATHODE RAY TUBE TYPE MX24

The MX24 is a magnetically focused, magnetically deflected c.r.t. with a metal cone, intended for radar display applications.

The fluoride phosphor type 00L65 has an aluminium backing to give maximum output.

CHARACTERISTICS

Mechanical

Overall length	30 in.	Spacing cathode screen	26½ in.
Neck diameter	36 mm.	Overall diameter	21⅝ in.
Useful screen diameter	19 in.	Deflection angle	60°

Electrical

	Max.	Typical	Min.
Heater Voltage	6.8 V	6.3V	5.8V
Heater Current		0.5A	
A2 Voltage	15.5kV	15kV	
A1 Voltage	600V	400V	
*Modulator voltage for cut off	-115V	-80V	-40V
Beam current	50µA		
*A1 Current	10µA		
*Line Width at 50µA (with specified coils)		0.5mm	
Deviation of unfocused spot from centre of screen.		20mm	
Deviation of unfocused spot from neck shadow.		13mm	
Capacitances. Modulator to all electrodes.		15pf.	
Cathode to all electrodes.		8pf.	

* VA_1 400V VA_2 15kV V_H 6.3

Base. B12A with metal shell.

Pin connections.

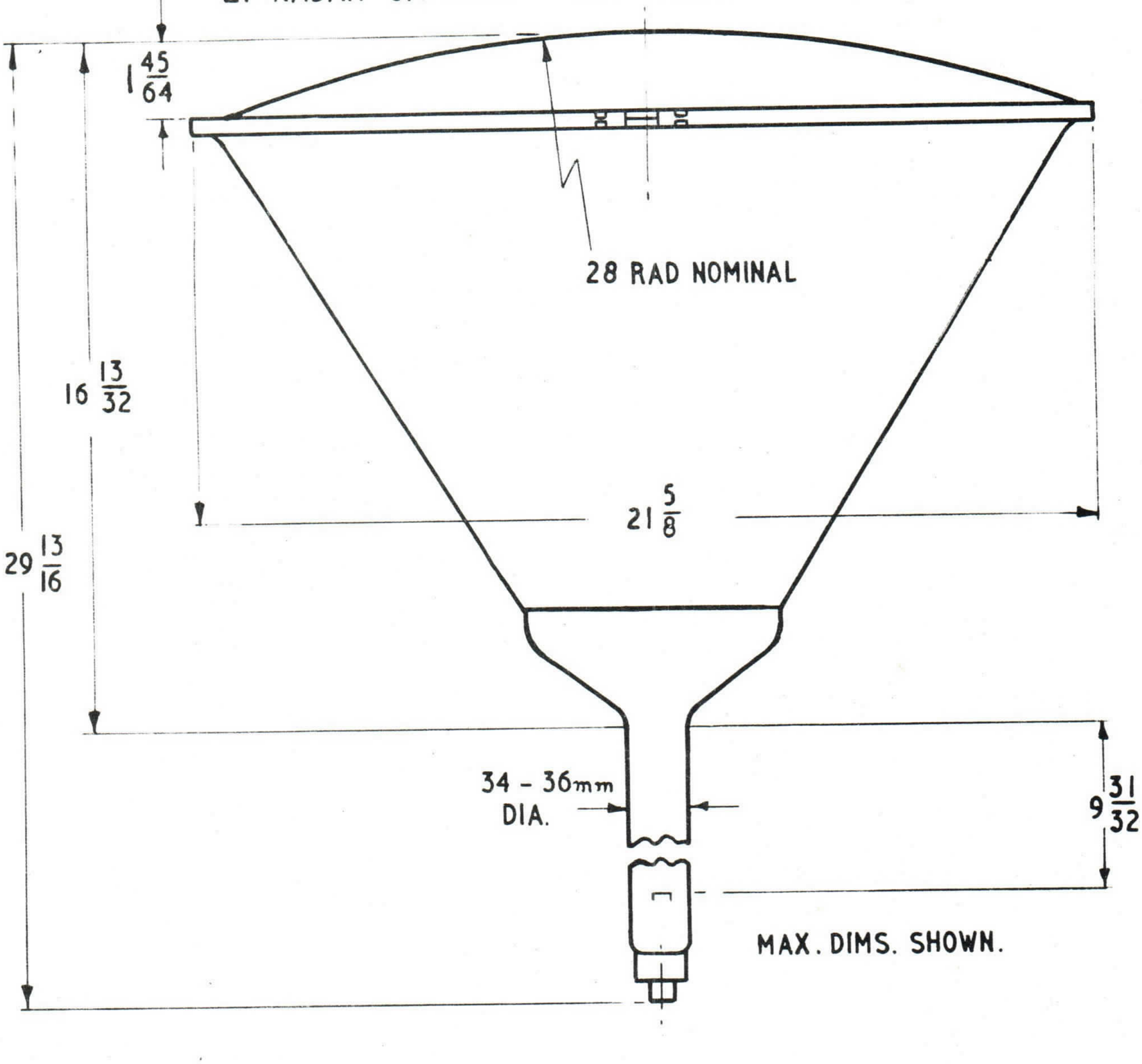
Pin	Electrode	Pin	Electrode
1	Heater	7	No connection
2	Modulator	8	No pin
3	No pin	9	No pin
4	No pin	10	A1
5	No pin	11	Cathode
6	No connection	12	Heater
		Cone	A2 (final anode)

To prevent damage to the screen material and to ensure that maximum life is obtained, the tube should not be operated with a stationary or slowly moving spot of high mean current density. The beam current should not exceed 50µa, while for maximum cathode life the heater voltage should be controlled as closely as possible to 6.3V.

(These tubes can be supplied to spec. CV.2388)

D.S.17.

21" RADAR CATHODE - RAY TUBE



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CATHODE RAY TUBE TYPE MX 27

(Prototype VCRX407)

Cathode ray tube type MX27 is a 5" diameter magnetically deflected tube with electrostatic focusing. Intended for use with a final accelerator voltage of 11 to 13kV, the small spot size and high brightness given by the tube make it suitable for many radar applications. The phosphor is aluminised willemite, but any standard phosphor, such as a fluoride, or a double layer long-afterglow screen, is available.

CHARACTERISTICS.

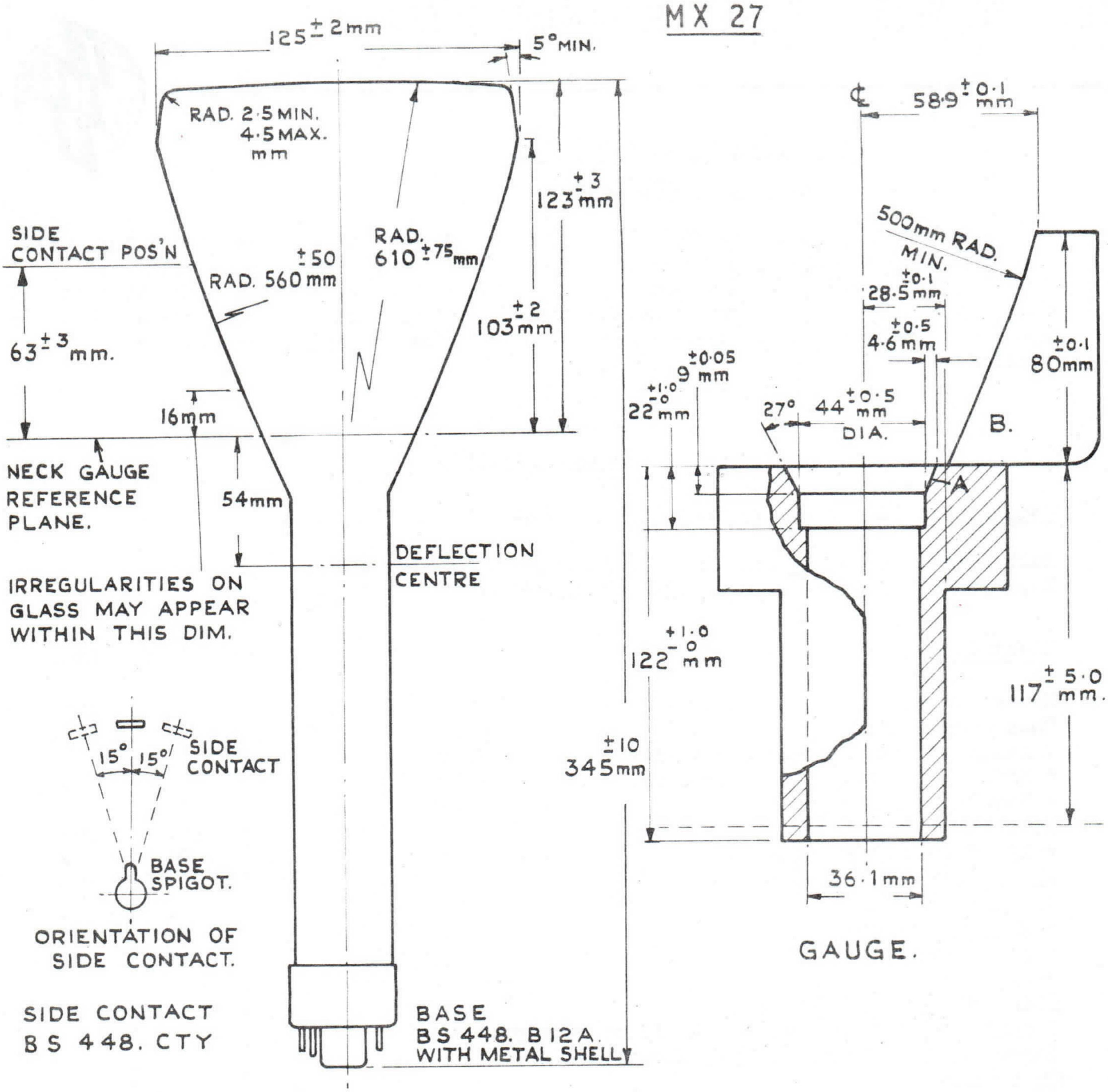
Mechanical (See fig. overleaf for bulb and neck gauge drawings)

Bulb diameter:	125 ± 2mm.	Useful screen diameter:	105mm min.
Neck diameter:	33.2mm min.	Overall length:	345 ± 10mm.

Electrical		Max.	Typical	Min.
Heater Voltage	Volts	6.8	6.3	5.8
Heater Current	Amperes	0.66	0.6	0.54
Voltage between cathode and heater	Volts	100		
* Modulator voltage (for cut-off)	Volts	-70		-30
* Modulator drive	Volts	27		
A1 voltage	Volts	350	300	250
* A3 voltage (for focus)	Volts	200	0	-200
A3 voltage (absolute)	Volts	500	-	-500
A2 and A4 voltage	Kilovolts	13	12	11
* Cathode current	Microamperes		250	
* A3 current	Microamperes		15	
* Beam current	Microamperes			
Modulator current (Vm-70V)	Microamperes	7		
Capacitance - Modulator to all Electrodes pf.		12		
Capacitance Cathode to all Electrodes pf.		12		
*Spot size	mm	0.5		
Deviation of undeflected spot from centre of screen.	mm	7		
Blemishes in screen or tube face	> Imm. dia.	0		
	> 0.5mm < 1mm.	6		
Spacing between blemishes	mm	-		15

* (V_{A1} 300V, $V_{A2\&4}$ 12kV, V_H 6.3V, Light intensity 2 candela
Voltages measured with regard to cathode.
The tube will operate with either anode or cathode at earth potential.

MX 27



NOTE:- THE EXTENDED NECK AXIS, DEFINED AS AXIS OF THE NECK GAUGE, SHALL NOT DEVIATE BY MORE THAN 2·0 mm FROM THE GEOMETRIC CENTRE OF THE SCREEN FACE PLANE.

WHEN THE TUBE IS ROTATED BY ONE REVOLUTION, LESS THE AREA OF IRREGULARITY NEAR THE SIDE CONTACT, WHILE MATING WITH THE 27° CONE OF THE NECK GAUGE, 'A', THE BULB SHALL NOT FOUL AGAINST VANE 'B'.

BASE CONNECTIONS: H = HEATER. M = MODULATOR. C = CATHODE IC = INTERNAL CONNECTION.

PIN	1	2	3	4	5	6	7	8	9	10	11	12	SIDE CONTACT
ELECTRODE	H	M	NO PIN			A3	IC	NO PIN		A1	C	H	A2 & A4

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EMI CATHODE RAY TUBE TYPE MX29 (R5161)

The MX.29 is an electromagnetically focused, electromagnetically deflected C.R.T., intended for use in Film Scanning equipment. The tube face is of special, non-solarising glass and is optically ground for flatness and thickness. A green, very short afterglow phosphor is used, and the neck has external sized dimples to facilitate easy setting up of the focus coil.

This tube is suitable for use with E.M.I. photomultiplier tubes, 6097F for monochrome, blue and green channels 9558 and 6095 for red channels.

CHARACTERISTICS

Mechanical

Overall length	19½ in. max.	495 mm.
Neck dia.	1.44 in.	36.5 mm.
Face dia.	6⅜ in.	162 mm.
Useful screen area	4 in. x 3 in.	100 mm. x 75 mm.
Deflection angle	50°	
Phosphor	Green - afterglow to 1/10th initial value - 10^{-5} secs.	

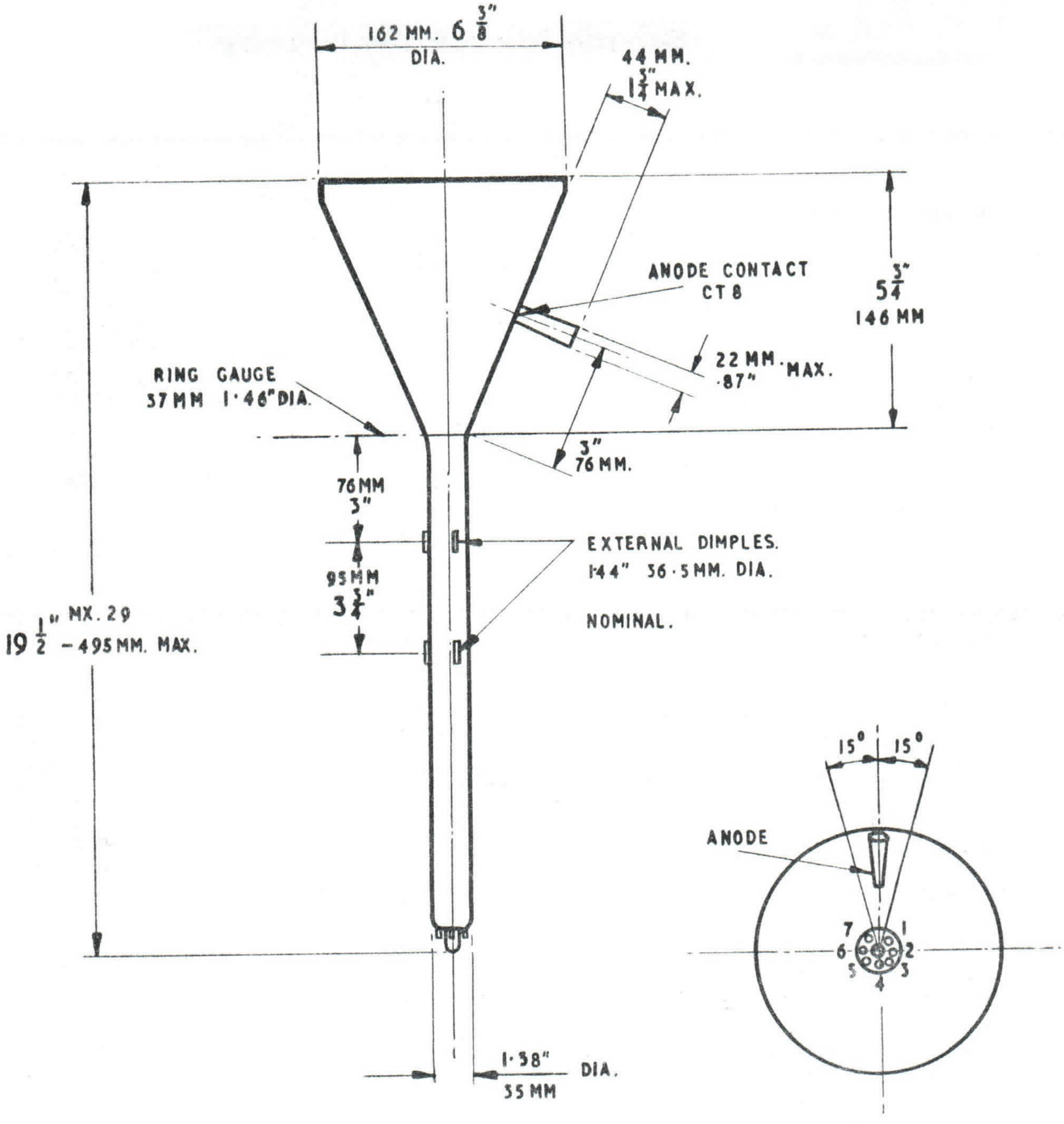
Electrical	Max.	Typical	Min.
Heater Voltage		4V	
Heater Current	1.1A	1.0A	0.8A
Final Anode Voltage		21KV	
Modulator cut-off voltage	-90V	-60V	-40V
Max. final anode voltage	28KV		
Deviation of unfocused spot from centre of screen	7 mm.		
Beam Current		300μA	
Spot Size	0.12 mm.	0.1 mm.	
Modulator/all capacitances	12 pf		
Cathode/all capacitances	12 pf		

Pin Connections

Base - B7B	Pin	1	2	3	4	5	6	7
		I.C	I.C	M	I.C	H	C	H

Side Contact - CT8

MX 29



TD

DS42/2.

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TD/1139/25M/1261/ LTD 40040

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EMI CATHODE RAY TUBE TYPE MX29S

The MX.29S is an electromagnetically focused, electromagnetically deflected C.R.T., intended for use in film scanning equipment. The tube face is of special, non-solarising glass, and is optically ground for flatness and thickness. A green, very short afterglow phosphor is used, and the neck has external sized dimples to facilitate easy setting-up of the focus coil. The MX.29S has been developed to give better overall focus than the MX.29, at the expense of focus at the centre of the tube.

This tube is suitable for use with E M I photomultiplier tubes, 6097F for monochrome, blue and green channels 9558 and 6095 for red channels.

CHARACTERISTICS

Mechanical

Overall length	17½ in	445 mm
Neck dia.	1.44 in	36.5 mm
Face dia.	6⅜ in	162 mm
Useful screen area	4 in x 3½ in	100 mm x 87 mm
Deflection angle	50°	
Phosphor	Green - afterglow to ⅒ th initial value - 10-5 secs.	

Electrical	Max.	Typical	Min.
Heater Voltage		4V	
Heater Current	1.1A	1A	0.8A
Final anode voltage		21KV	
Grid cut-off voltage	-120V	-90V	-60V
Max. final anode voltage	28KV		
Deviation of unfocused spot from centre of screen	7 mm		
Beam current		300μA	
Spot Size	0.14 mm	0.12 mm	
Grid/all capacitances	12 pf		
Cathode/all capacitances	12 pf		

Pin Connections

Base B7B	Pin	1	2	3	4	5	6	7
		I.C.	I.C	G	I.C	H	C	H

Side contact - CT8

EC8/C/116
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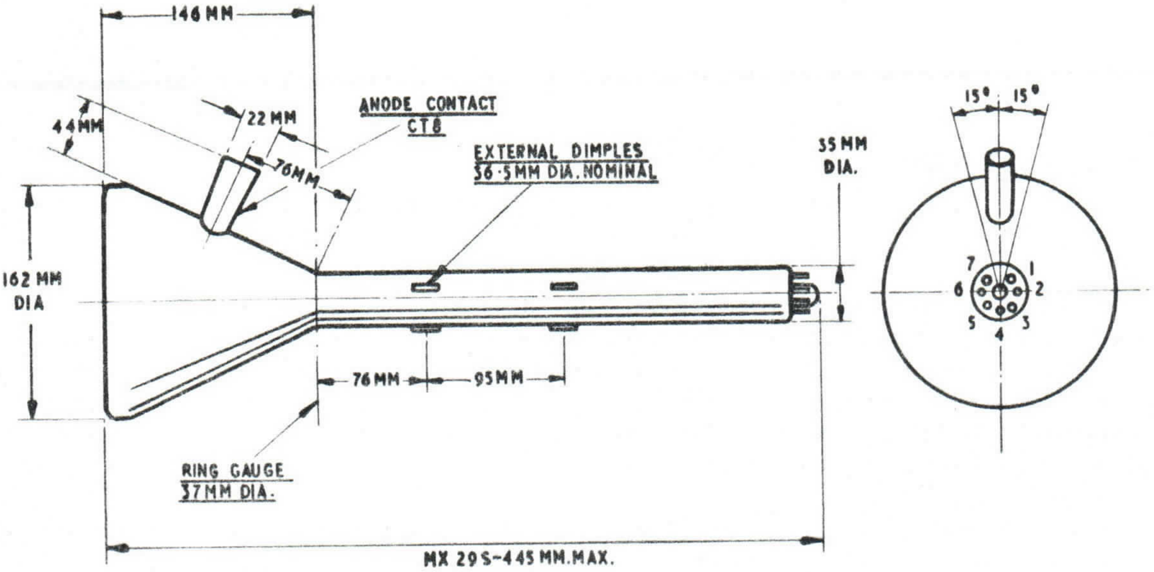
TD



DS60/2.

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MX.30 (CV.1738)

The MX.30 is a 6" magnetically focussed, magnetically deflected Cathode Ray Tube, intended for use in low frequency film scanning equipment where a low intensity beam is required to prevent screen burning and where random variations in bias voltages can affect the performance of the equipment. The tube has a low slope characteristic which is approximately linear over the working region and the maximum current available is limited, to prevent screen burning. The tube face is optically ground for flatness and thickness; and a green, very short persistence phosphor is used.

Characteristics

MECHANICAL	Inches.	Millimeters.
Overall length	$19\frac{3}{8}$ max.	490 max.
Neck diameter	1.44 max.	36.5 max.
Face diameter	$6\frac{3}{8}$ max.	1.62 max.
Useful screen area	$5\frac{1}{4}$ min.	133 min.
Deflection angle	50°	

Phosphor - Green - aluminium backed.
Afterglow 10-5 secs. to 1/10th of initial value.

ELECTRICAL	Max.	Typical.	Min.
Heater voltage		4 volts	
Heater current	1.1 A	1.0 A	0.8 A
Final anode	25kV	22kV	
Grid voltage for cut-off at VA = 22kV	-70 V	-50 V	-30 V
Maximum intensity of illumination	0.7 cdls.		
Line width	0.15 mm.		
Deviation of unfocussed spot from centre of screen	7 mm.		

Capacitances

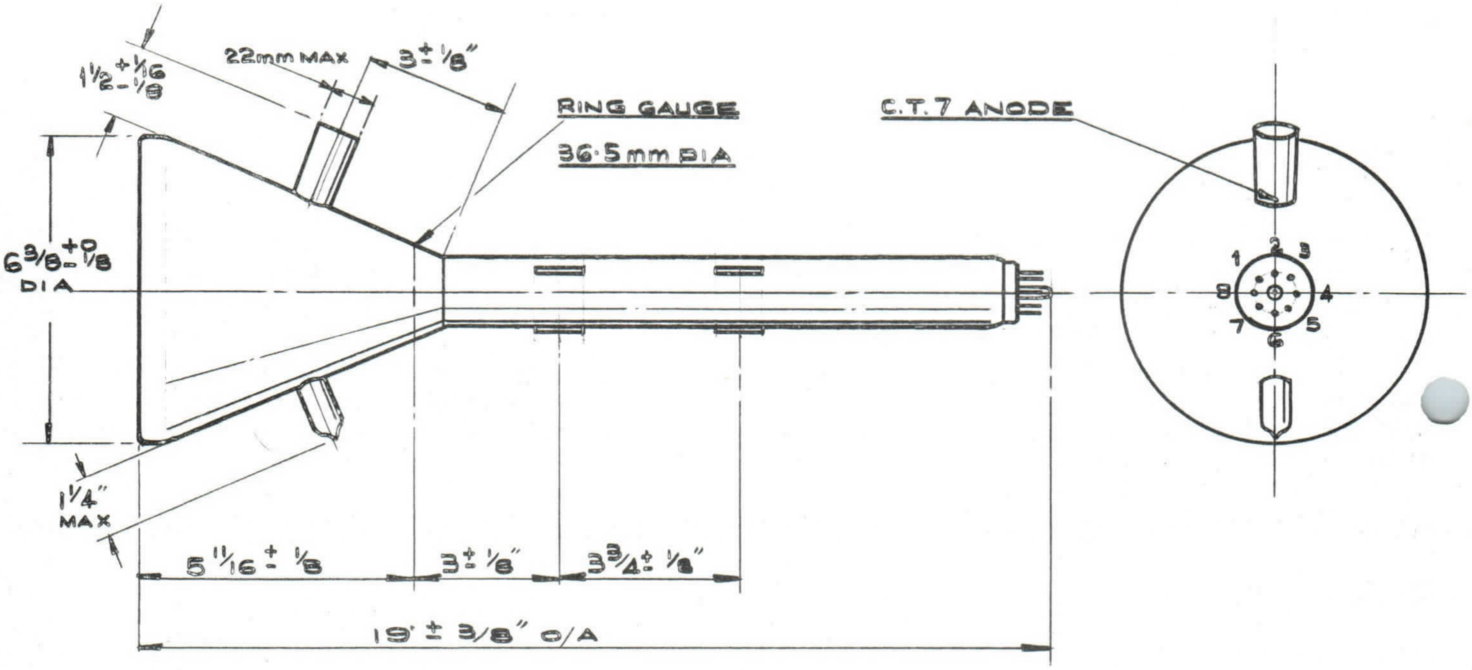
Grid/all	12 p.f.
Cathode/all	12 p.f.

BASE - B8G - side contact CT7

Pin Connections:

1	2	3	4	5	6	7	8
I.C.	Htr.	I.C.	I.C.	Grid.	I.C.	Htr.	Cathode

MX 30



EC8/35
14.9.60.

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MX31 (CV2305)

The MX31 is a 12" magnetically focused magnetically deflected CRT with an orange, long afterglow phosphor intended for use in PPI radar displays.

Characteristics

Mechanical

Overall length	20.5" max	520mm max
Neck diameter	1.38"	36mm
Face diameter	12.2" max	310mm max
Useful screen diameter	10" min	250mm min
Deflection angle	50°	

Phosphor Orange aluminium backed

Persistence to $\frac{1}{100}$th of initial value 60 secs.

Electrical	Max	Typical	Min
Heater voltage		6.3V	
Heater current	0.6A	0.55A	0.5A
Final Anode Voltage V_{A2}	15KV	15KV	
First Anode Voltage V_{A1}	600V	300V	
Grid Voltage for cut-off at V_{A1} = 300V	-90	-60V	-30V
Line width at 50 µA	0.5mm	0.4mm	
Deviation of unfocused spot from centre of screen	15mm		

Capacitances

G/all	15pF
C/all	8pF

Base B12A

Pin connections	1	2	3	4	5	6	7	8	9	10	11	12
	H	G	-	-	-	NC	NC	-	-	A1	C	H

Side Contact A2

To prevent damage to the screen material the tube should not be operated with a stationary or slowing moving spot of high current density. The tube should be operated at its minimum useful brightness, i.e. max. beam current 50 µA.

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MX32 CATHODE RAY TUBE
(PROTOTYPE VX.5074)

The MX32 is a magnetically focused, magnetically deflected C.R.T., intended for use in projection radar displays. The specially developed phosphor is capable of producing an extremely high light output without phosphor loading, and the front face is of special, blemish-free, non-solarising glass. The tube can be fitted with an external collar, which accurately locates the tube electrically and optically, thus considerably minimising the difficulties in setting-up the tube in an optical system.

CHARACTERISTICS

Phosphor	Peak Wavelength	Afterglow 1/10th of initial value
Blue	4350 Å	2 msec.

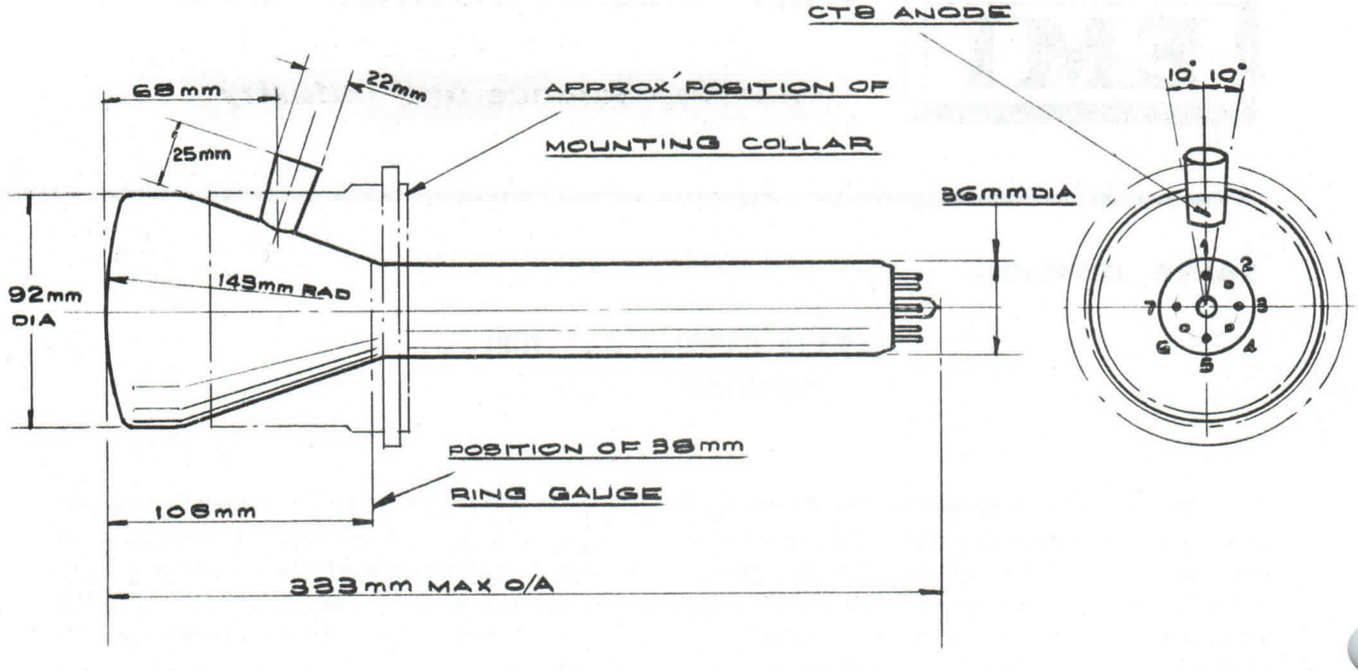
Mechanical

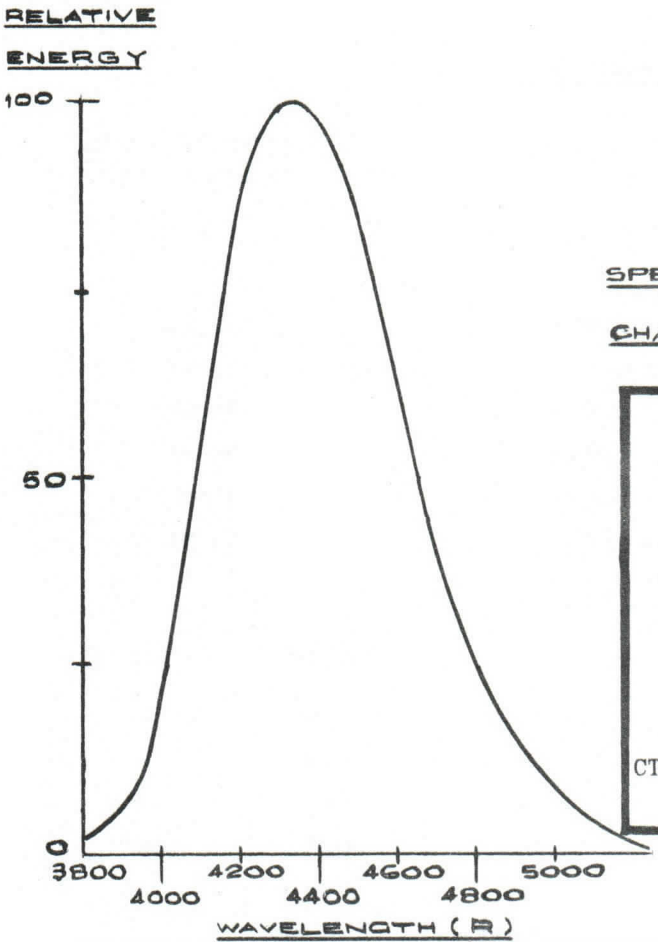
Overall length (max.)	13.7 inches	333 mm.
Neck dia. (nominal)	1.38 inches	35 mm.
Useful Screen dia. (min.)	3.2 inches	84 mm.
Overall dia. (max.)	3.65 inches	93 mm.
Radius of curvature of face plate	5.62 inches	143 mm.
Front face glass thickness	0.154 inches	3.75 mm.
Deflection Angle	40°	

Electrical	Max.	Typical	Min.
Heater voltage	6.8V	6.3V	5.8V
Heater Current		0.5A	
Anode Voltage	30KV	28KV	
* Modulator Voltage for Cut-off	200V	150V	100V
Beam Current		3 mA	
Line Width at 500 μA	0.3mm	0.25 mm	
Deviation of unfocused spot from centre of face	5 mm		
Capacitance Mod./all	15pF		
Cath/all	12pF		

* V_{Anode} 28KV

MX 32





SPECTRAL EMISSION

CHARACTERISTICS

Base Connections

Pin	Electrode
1	H_1
2	N.C.
3	G
4	H_1
5	H_2
6	C
7	H_1
CT8 Side Contact	Anode

Base - B7B

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TD/1128/25M/961/ 39535

VALVE DIVISION

PROVISIONAL SPECIFICATION

BINARY ENCODING TUBE TYPE MX.34

The MX.34 is a cathode ray tube in which a coding plate is electrostatically scanned by the electron beam, the plate consisting of a number of apertures located in a configuration which will produce binary digital information. When a signal is applied to the Y plates the beam takes up a certain level corresponding to the signal voltage. If the beam is then scanned by a saw-tooth voltage in the X direction an output can be obtained as a series of pulses, each set uniquely defining the amplitude of the Y co-ordinate as binary information output can be obtained, either as an electrical signal from the collector mesh, or as a visible signal from the phosphor using a photomultiplier to convert back to an electrical signal with considerable amplification if required.

CHARACTERISTICS

Mechanical

Overall length	10.5 in max.	267 mm max.
Face diameter	3 in	76 mm
Phosphor	Blue or Green very short afterglow	

Electrical	Max.	Typical	Min.
Code - 6 digit continuous progressive code			
Heater voltage		6.3V	
Heater current	0.6A	0.55A	0.5A
de voltage VA3	4KV	2KV	
Grid voltage for cut-off at VA3 = 2KV	-80V	-50V	-20V
Focus voltage VA2	500V	300V	200V
Beam current (output current)		10μA	
Deflection Voltage for fullscale deflection at VA3 = 2KV Y		140V	
X		100V	
Max frequency of X scan		1 Mc/s	

Pin Connections

Base 12 pin glass	1	2	3	4	5	6	7	8	9	10	11	12
	H	H	C	-	Code Plate	G	-	A2	-	A3	-	-

Side Connections

X_1 X_2 Y_1 Y_2 Output mesh.

It is possible to increase the number of digits in the binary code up to a maximum of 10 digits with a corresponding increase in the physical size of the tube.

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Provisional Specification.

MX 34

Binary Encoding Tube

The MX34 is a cathode ray tube in which a coding plate is electrostatically scanned by the electron beam, the plate consisting of a number of apertures located in a configuration which will produce binary digital information. When a signal is applied to the Y plates the beam takes up a certain level corresponding to the signal voltage. If the beam is then scanned by a saw-tooth voltage in the X direction an output can be obtained as a series of pulses, each set uniquely defining the amplitude of the Y co-ordinate as binary information. The output can be obtained, either as an electrical signal from the collector mesh, or as a visible signal from the phosphor using a photo multiplier to convert back to an electrical signal with considerable amplification if required.

Characteristics.

Mechanical:

Overall length	10.5" max.	267 mm max.
Face diameter	3"	76 mm

Phosphor: Blue or Green very short afterglow

Electrical:

Code - 6 digit continuous progressive code

	Max.	Typical	Min.
Heater voltage		6.3V	
Heater current	0.6A	0.55A	0.5A
Anode voltage VA3	4KV	2KV	
Grid voltage for cut-off at VA3 = 2KV	-80V	-50V	-20V
Focus voltage VA2	500V	300V	200V
Beam current (ouput current)		10µA	
Deflection Voltage for fullscale deflection at VA3 = 2KV Y X		140V 100V	
Max frequency of X scan		1 Mc/s	

Contd./.

Base 12 pin glass

Pin connections	1	2	3	4	5	6	7	8	9	10	11	12
	H	H	C	–	Code Plate	G	–	A2	–	A3	–	–

Side connections	X_1	X_2	Y_1	Y_2	Output mesh.

It is possible to increase the number of digits in the binary code up to a maximum of 10 digits with a corresponding increase in the physical size of the tube.

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MX.33 (CV2372)

The MX.33 is a 9" flat-faced, magnetically focused, magnetically deflected CRT with an orange long afterglow phosphor intended for use in Radar displays.

Characteristics

Mechanical

Overall length	18.8" max	477mm max
Neck diameter	1.42"	36mm
Face diameter	$9\frac{1}{4}$" max	236mm max
Useful screen diameter	$7\frac{7}{8}$" min	200mm min
Deflection angle	40°	

Phosphor Orange long afterglow aluminium backed.

Persistence to $\frac{1}{100}$ th of initial value 180 secs.

Electrical

	Max	Typical	Min
Heater Voltage		6.3V	
Heater current	0.6A	0.55A	0.5A
Final Anode Voltage VA	15.5KV	15KV	
Grid voltage for cut-off at V_A = 15KV	-140V	-100V	-60V
Line width at 20 µA beam current	0.25mm	0.2mm	
Deviation of unfocused spot from centre of screen	10mm		
Capacitances			
G/all	15pF		
C/all	10pF		

Base B12A Pin connections

1	2	3	4	5	6	7	8	9	10	11	12
H	G	–	–	–	NC	NC	–	–	NC	C	H

To prevent damage to the screen material the tube should not be operated with a stationary or slowly moving spot of high current density. The tube should be operated at its minimum useful brightness.

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MX 35 (Provisional Specification)

Binary Decoding Tube

The MX 35 is a special cathode ray tube designed for use in systems used to convert binary signals to analogue signals. The tube is designed to separate the digital information contained in a signal and pass this information onto a suitable integrating system. A binary signal consists of a number of sequential pulses the absence or presence of which on a time scale designate the analogue value of the signal. In order to decode the signal the pulses must be separated into individual channels and delayed so that they can be read off simultaneously. The MX 35 is designed for use in 6 digit systems and the electron beam is scanned across 6 collector plates at a frequency corresponding to the length in time of each set of pulses and synchronised with the signal. Modulation of the beam by the digital information allows the beam to impinge on the appropriate collector plates when these pulses occur. The output pulses can then be fed into Eccle-Jordan trigger circuits or any convenient delay system and be read off simultaneously at any arranged time.

Characteristics

Mechanical:

Overall length	9"
Max diameter	3"

Electrical:

Heater voltage	6.3V
Heater current	2A
Anode voltage VA3	1KV
Focus voltage VA2	300V
Beam current (output current)	300μA

Deflection voltage
for full scale deflection 100V

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MX.37

(CV.2415)

The MX.37 is an electrostatically focused, magnetically deflected C.R.T. with an orange, long afterglow phosphor with aluminium backing, intended for radar display applications.

Characteristics

Mechanical

Overall Length	15.4"	390 mm.
Neck Diameter	1.38"	35 mm. max.
Useful Screen Diameter	5.3"	135 mm.
Face Diameter	6.3"	160 mm.
Deflection Angle	40°	

Phosphor - Orange - long persistence

Electrical	Max.	Typical	Min.
Heater Voltage		4V	
Heater Current	1.2A	1.0A	0.7A
Final Anode Voltage	8kV	7kV	
First Anode Voltage	1450V	1250V	
Second Anode Voltage	1400V	1000V	900V
Cut-off Voltage	-100V	-50V	-30V
Beam Current	50µA		
Spot Size	0.8mm.	0.6mm.	
Deviation of unfocused spot	10mm.		
Grid/all Capacitance	25p.f.	10p.f.	

Base B8/0

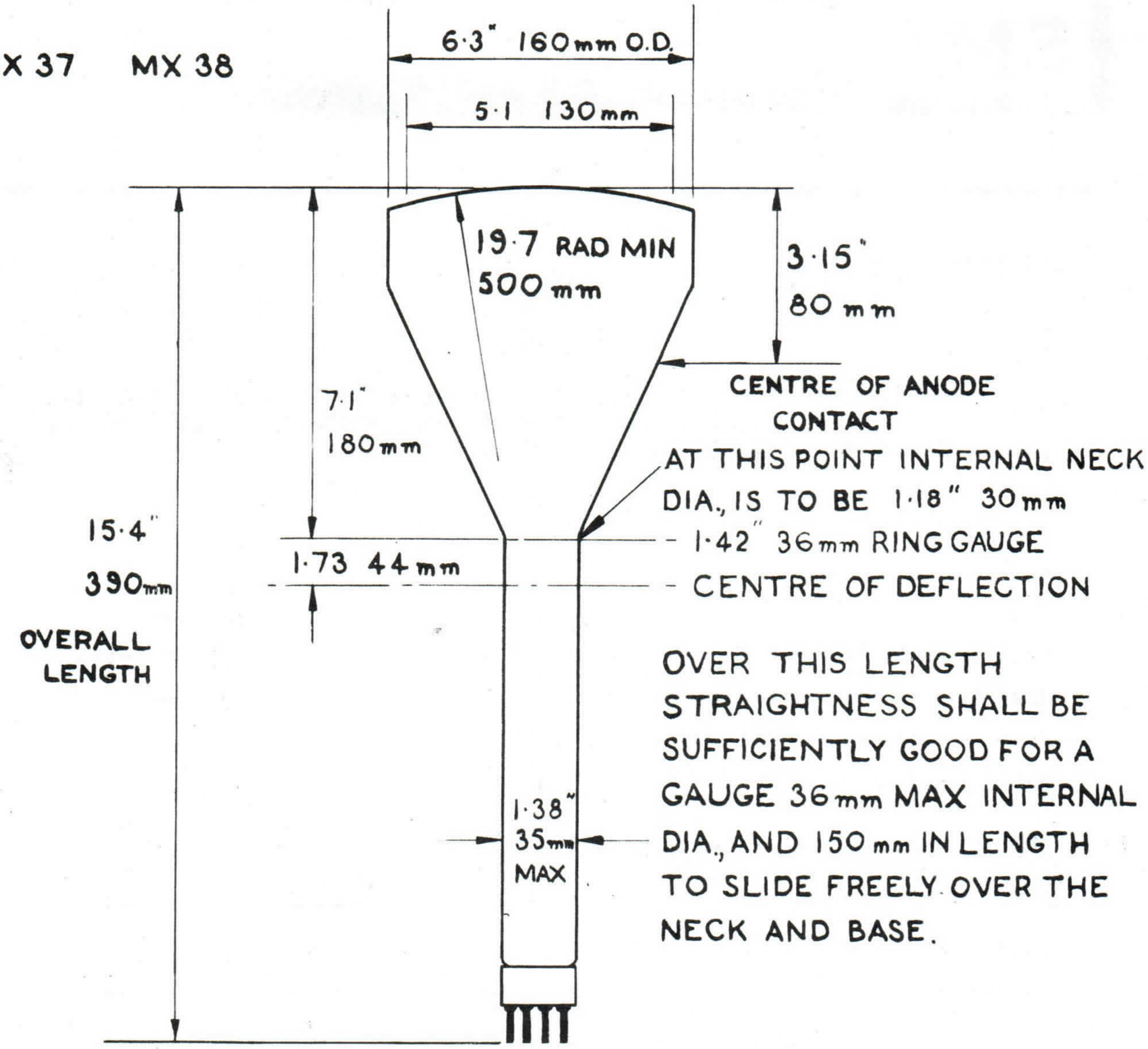
Pin Connections

1.	N/C
2.	A1
3.	A2
4.	N/C
5.	G
6.	C
7.	H
8.	H

Side Contact CT8 Final Anode

To prevent damage to the phosphor, the tube should not be operated with a stationary or a slowly moving spot of high current density. The tube should be operated at its minimum useful brightness.

MX 37 MX 38



CENTRE OF ANODE CONTACT

AT THIS POINT INTERNAL NECK DIA., IS TO BE 1·18" 30mm

1·42" 36mm RING GAUGE

CENTRE OF DEFLECTION

OVER THIS LENGTH STRAIGHTNESS SHALL BE SUFFICIENTLY GOOD FOR A GAUGE 36mm MAX INTERNAL DIA., AND 150mm IN LENGTH TO SLIDE FREELY OVER THE NECK AND BASE.

THE ANGLE BETWEEN THE PLANES THROUGH THE TUBE AXIS, THE CENTRE OF THE SIDE CONTACT, THE TUBE AXIS AND THE KEY IN THE SPIGOT OF THE BASE SHALL NOT BE MORE THAN ±10°

The Company reserves the right to modify these designs and specifications without notice.

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EMI Electronics Ltd Valve Division

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Printed in England by E.M.I. Ltd.

VALVE DIVISION

MX.38
(CV.1530)

The MX.38 is an electrostatically focused, magnetically deflected C.R.T. with a green, medium persistence phosphor with aluminium backing.

Characteristics

Mechanical

Overall Length	15.4"	390 mm.
Face Diameter	6.3"	160 mm.
Neck Diameter	1.38"	35 mm. max.
Deflection Angle	40°	
Useful Screen Diameter	5.3"	135 mm.

Phosphor - Green - medium persistence

Electrical	Max.	Typical	Min.
Heater Voltage		4V	
Heater Current	1.2A	1.0A	0.7A
Final Anode Voltage	8kV	7kV	
First Anode Voltage	1450V	1250V	
Second Anode Voltage	1400V	1000V	900V
Cut-off Voltage	-100V	-50V	-30V
Beam Current	250µA		
Spot Size	0.8mm.	0.6mm.	
Deviation of unfocused spot	10mm.		
Grid/all capacitance	25p.f.	10p.f.	

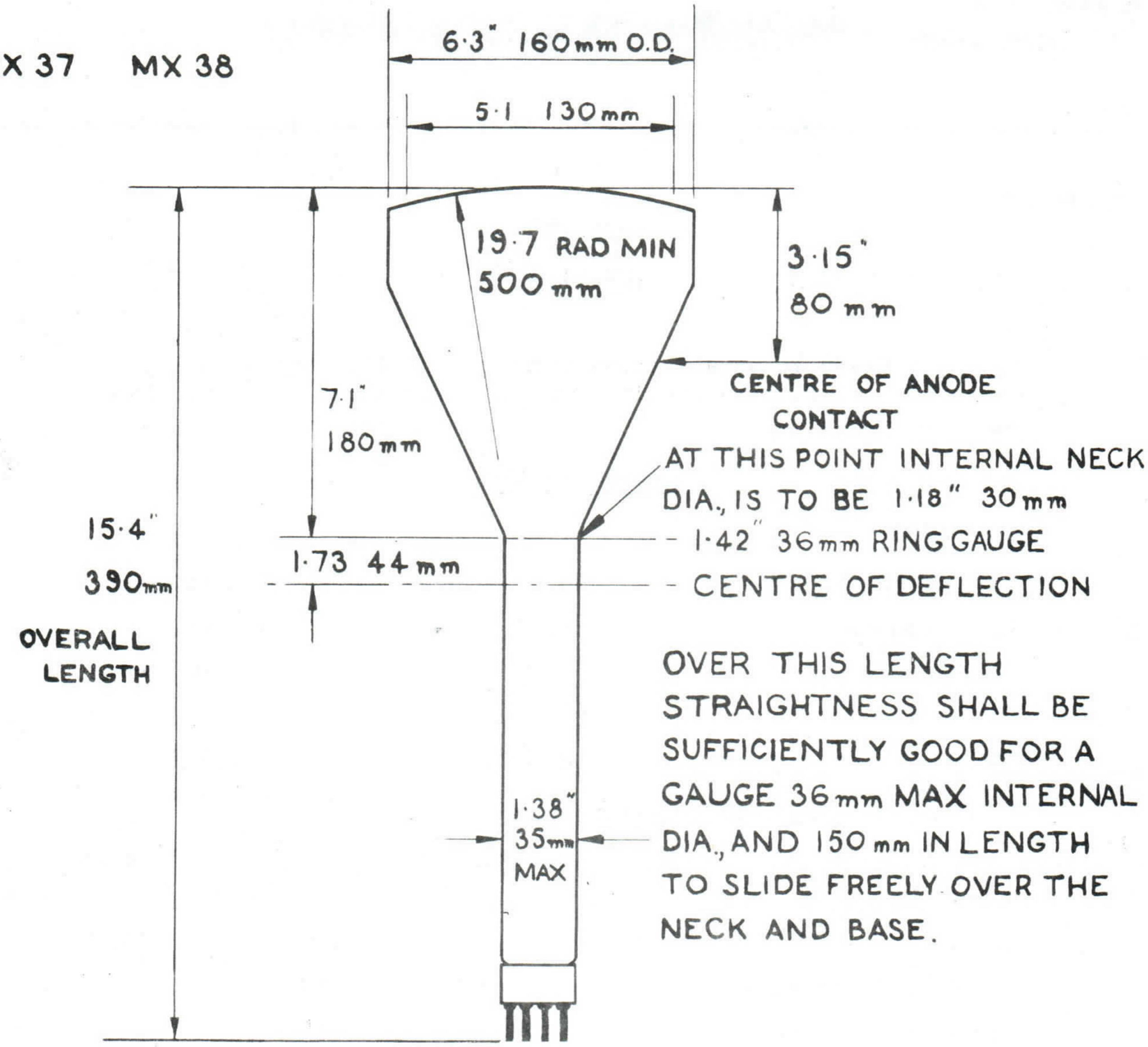
Base - B8/0

Pin Connections

1.	N/C
2.	A1
3.	A2
4.	N/C
5.	G
6.	C
7.	H
8.	H

Side Contact CT8 Final Anode

MX 37 MX 38



THE ANGLE BETWEEN THE PLANES THROUGH THE TUBE AXIS, THE CENTRE OF THE SIDE CONTACT, THE TUBE AXIS AND THE KEY IN THE SPIGOT OF THE BASE SHALL NOT BE MORE THAN ±10°

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VALVE DIVISION

RIBBON BEAM TUBE - TYPE MX 39

The MX 39 is an electrostatically focused and deflected cathode ray tube, producing a ribbon shaped beam, and it is intended for use in variable area recording. Deflection of the ribbon beam is provided only along its length, the deflection at right angles being effectively provided by a moving film. For high sensitivity photographic recording a blue phosphor is used.

CHARACTERISTICS

Mechanical

Overall Length	12"	305 mm. max.
Overall diameter	2.72"	69 mm.
Neck diameter	1.65"	42 mm. max.

Electrical

Heater Voltage	6.3 V
Heater Current	1 A
1st Anode Voltage	3kV w.r.t. cathode
2nd & 4th Anode Voltage (internally connected)	4kV w.r.t. cathode
3rd Anode Voltage (focus)	2.5kV - 1.5kV w.r.t. cathode
Cut-off Voltage	-20 V to -10 V
Line Width	1 mm. max
Line Length	15 mm. min.
Deflection Sensitivity a symmetrical defln.	$\frac{120}{VA4}$ mm/V
Deflection Length	30cm.
Cath/all capacitance	10 p.f. max.
Grid/all capacitance	10 p.f. max.
Either deflection plate/ all capacitance	15 p.f. max.

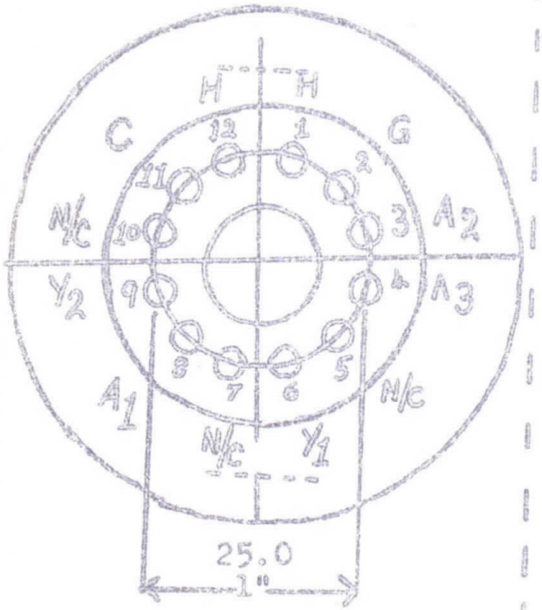
BASE - Pin Connections.

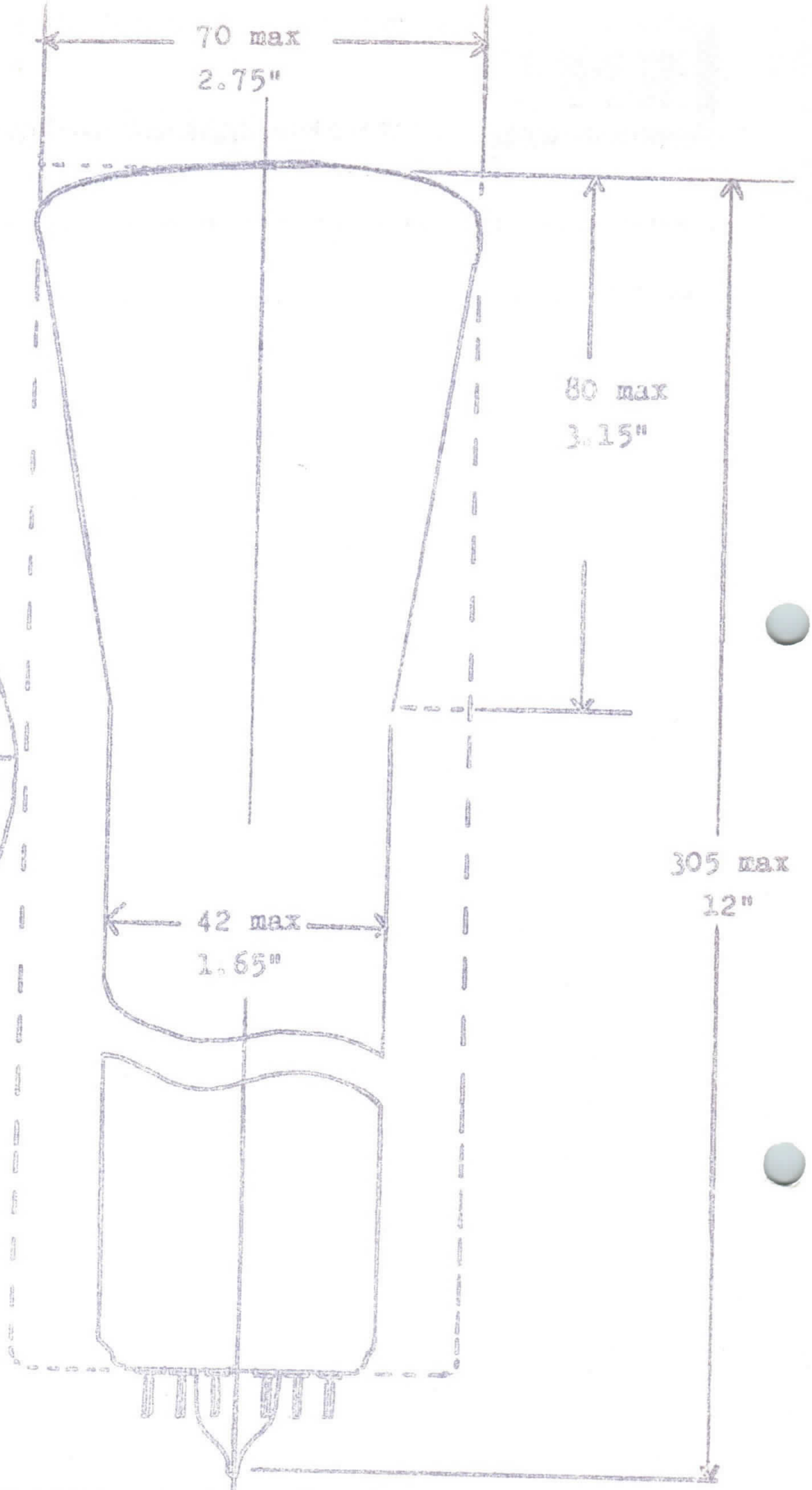
1	2	3	4	5	6	7	8	9	10	11	12
H	G	A_2	A_3	N/C	Y_1	N/C	A_1	Y_2	N/C	C	H

H = Heater G = Grid C = Cathode.

RIBBON BEAM
OUTLINE DRAWING

MX 39





All dimensions in
millimetres

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Cathode Ray Tube Type MX.41.

The MX.41 is a 10", magnetically focussed, magnetically deflected Cathode Ray Tube with a white T.V. aluminised screen, intended for use in T.V. monitors.

CHARACTERISTICS

Mechanical	Inches	Millimeters.
Overall length	19$\frac{3}{8}$ max.	490
Neck diameter	1.42	36
Face diameter	10.1/16 max.	256
Useful screen diameter	9	228
Deflection Angle	50°	

Phosphor - White

Electrical	Max.	Typical.	Min.
Heater Voltage		4 volts	
Heater Current	1.1 A	1.0 A	0.8 A
Final Anode Voltage	10 kV	7 kV	
First Anode Voltage	400 V	250 V	
Grid Voltage for c.o. (VA_1 = 250V)	-45 V	-30 V	-20 V
Spot Centrality	10 mm.		

BASE - B7B

Pin Connections :

1	2	3	4	5	6	7	Side Contact
I.C.	A_1	G	I.C.	H	C	H	Final Anode

EC8/36
15.9.60.

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CATHODE RAY TUBE TYPE MX.42

The MX.42 is a 9 in. electrostatically focused magnetically deflected CRT with an orange long afterglow phosphor.

CHARACTERISTICS

Mechanical

Overall length	18 in.	450 mm
Neck diameter	1.42 in.	36 mm
Face diameter	9¼ in.max.	236 mm max.
Useful screen diameter	7⅞ in.min.	200 mm min.
Deflection Angle	40°	

Phosphor

Orange long afterglow aluminium backed

Persistence to 0.01 times initial value 100 seconds

Electrical

	Max.	Typical	Min.
Heater voltage		6.3V	
Heater current	0.6A	0.55A	0.5A
Final Anode Voltage VA3 A1 internally connected to A3	15KV	15KV	
Modulator voltage for cut-off at VA3 = 15KV	-90V	-65V	-40V
2nd Anode voltage for focus VA2	+300V	OV	-300V
Line width at 30µA	0.5 mm	0.4 mm	
Deviation of undeflected spot from centre of screen	6 mm		
Capacitances			
M/all	15pF		
C/all	10pF		

Base B7B

Pin connections	1	2	3	4	5	6	7
	IC	IC	C	H	H	M	A2

Side contact CT8 A3

To prevent damage to the screen material the tube should not be operated with a stationary or slowly moving spot of high current density. The tube should be operated at its minimum useful brightness.

TD

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MX45 CATHODE RAY TUBE PROVISIONAL DATA

CRTM

The MX45 is a very high resolution CRT with electromagnetic focus and electromagnetic deflection. With a usable screen diameter of 5 inches it is possible to display 5000 resolvable lines at a beam current of 1 μA. The tube face is of high quality, bubble free, non solarising glass polished to a flatness better than 0.0005". The green phosphor is blemish free over a given area and is of minimum grain size so that the brightness variation along a scanned line does not vary by more than 10%. This tube is ideally suited for line-scan applications where the information is required on a permanent photographic record.

Typical Operating Conditions

Anode Voltage 8KV (20KV max.)
Cut-off voltage 25V - 60V

Heater voltage 6.3V

Heater current 0.55A

These tubes can be supplied with an external collar which is located with respect to both the phosphor plane to facilitate easy setting up in an optical system and to the electron beam to facilitate easy setting up of the focus coil.

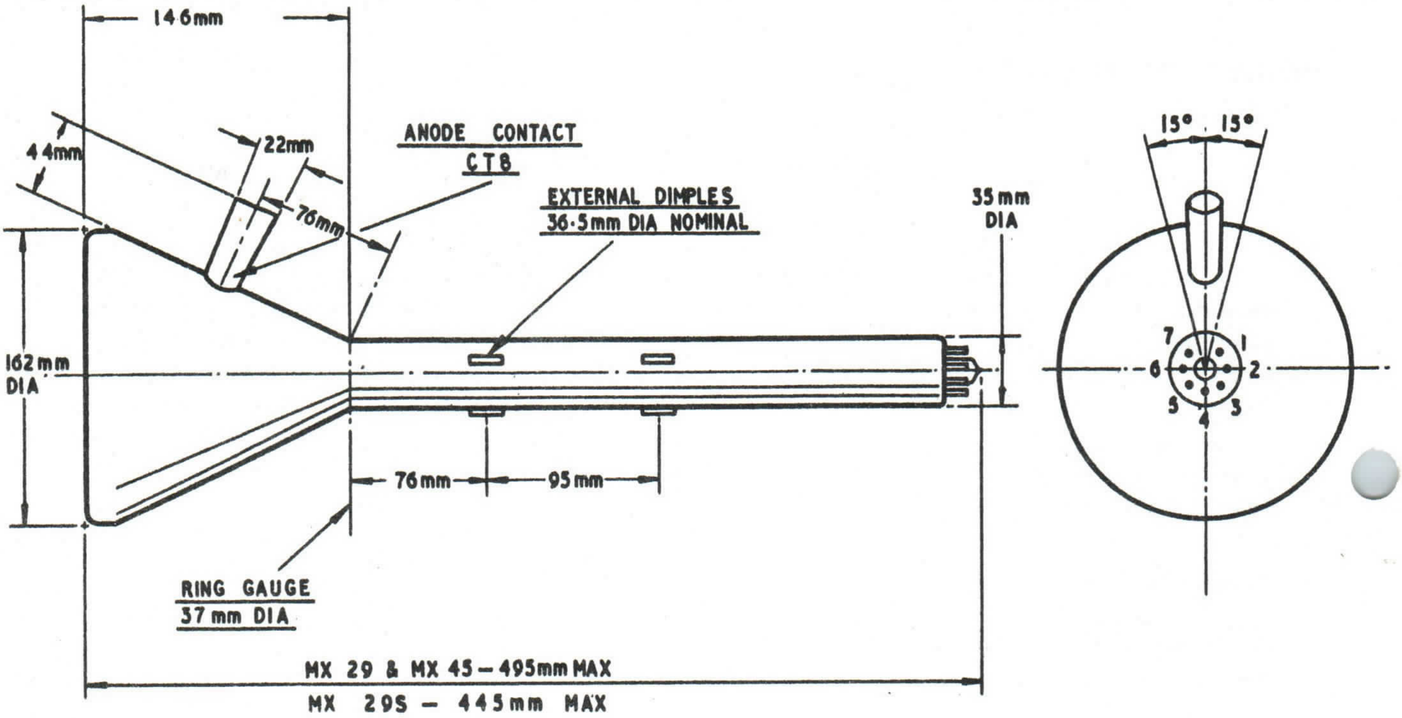
Physical Dimensions

Tube length 19½"

Face diameter 6⅜"

Neck diameter 35 mm

EC8/57
7.2.61.



MX 29, 29s & 45.

TD

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TD/1104/25M/461/ CTb 38751

MX46

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CATHODE RAY TUBE TYPE MX 46.

VALVE DIVISION

The MX 46 is a 5" high speed oscilloscope tube with an aluminium backed blue phosphor, polished flat screen and high ratio post-deflection acceleration enabling high resolution single transient pulses with rise times better than 5 mu secs. to be recorded photographically. The tube has been designed to have good deflection sensitivity in both the X and Y directions together with a high writing speed characteristic whilst the small diameter neck has kept the deflection plate capacities to a minimum.

A collar is provided, attached to the tube, which provides a firm and rigid mounting point for the tube. The collar is located on the tube so that a ground surface on the collar is parellel to , and at a fixed distance from, the apparent position of the phosphor plane as viewed from the front of the tube. This enables the tube to be mounted so that a camera can be attached with respect to the equipment and no focusing mechanism is required for the camera.

Replacement of tubes is also much simplified. The collar can also be provided with mounting holes which orientates the tube with respect to the scanning axes, providing also a positive location for the mu-metal shield.

CHARACTERISTICS.

MECHANICAL

Overall length	23"	584 m.m.
Face diameter	5.3"	134.6 m.m.
Neck diameter	1.38"	35 m.m.
Phosphor	Blue Zinc Sulphide short persistence.	

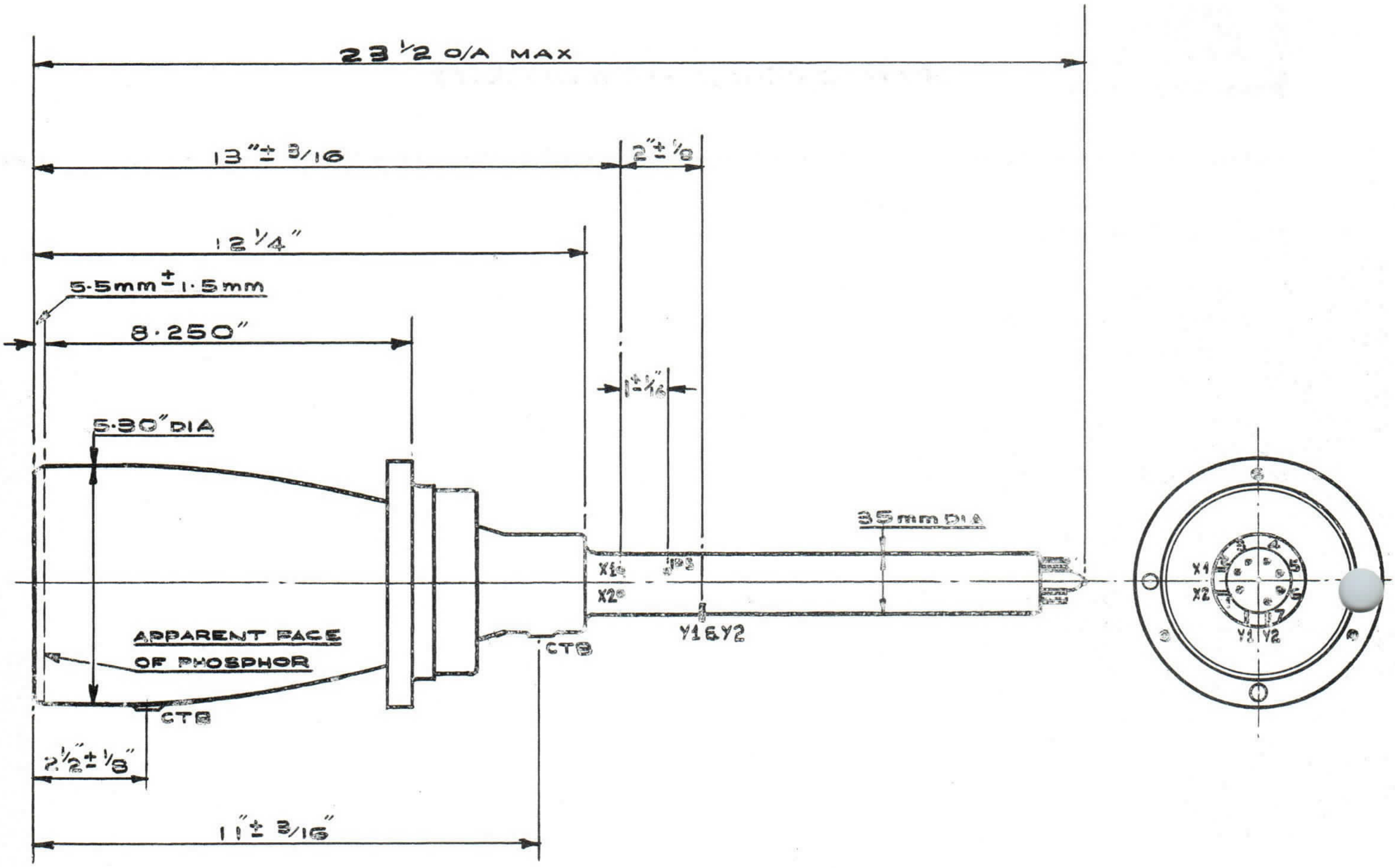
ELECTRICAL

	Maximum	Typical	Minimum
Heater Voltage		6.3V	
Heater Current	0.6A	0.55A	0.5A
V_{A5} PDA	20KV	16KV	
V_{A4}		0V	
V_{A3}		0V	
V_{A2} with V_C = -4KV	-3.5KV	-3.7KV	-3.9KV
V_{A1}	0V	-2KV	-3KV
V_C		-4KV	
V_g for cut-off w.r.t. V_C at V_C = -4KV	-200V	-150V	-100V

/continued ...

TD

MX46



	Maximum	Typical	Minimum
Line Width at 100V drive under typical operating conditions		0.2 mm.	
Deflection Sensitivity under typical operating conditions	X	0.255 mm/V	
Both X & Y plates are designed for symmetrical deflection	Y	0.375 mm/V	
Useful screen area under typical operating conditions	X	40 mm.	

Undeflected spot position under typical operating conditions : With the tube shielded the undeflected spot will be within a radius of 5 m.m. of the geometrical axis of the tube face.

/continued ....

TD

EC8/7-R2
16.3.61.

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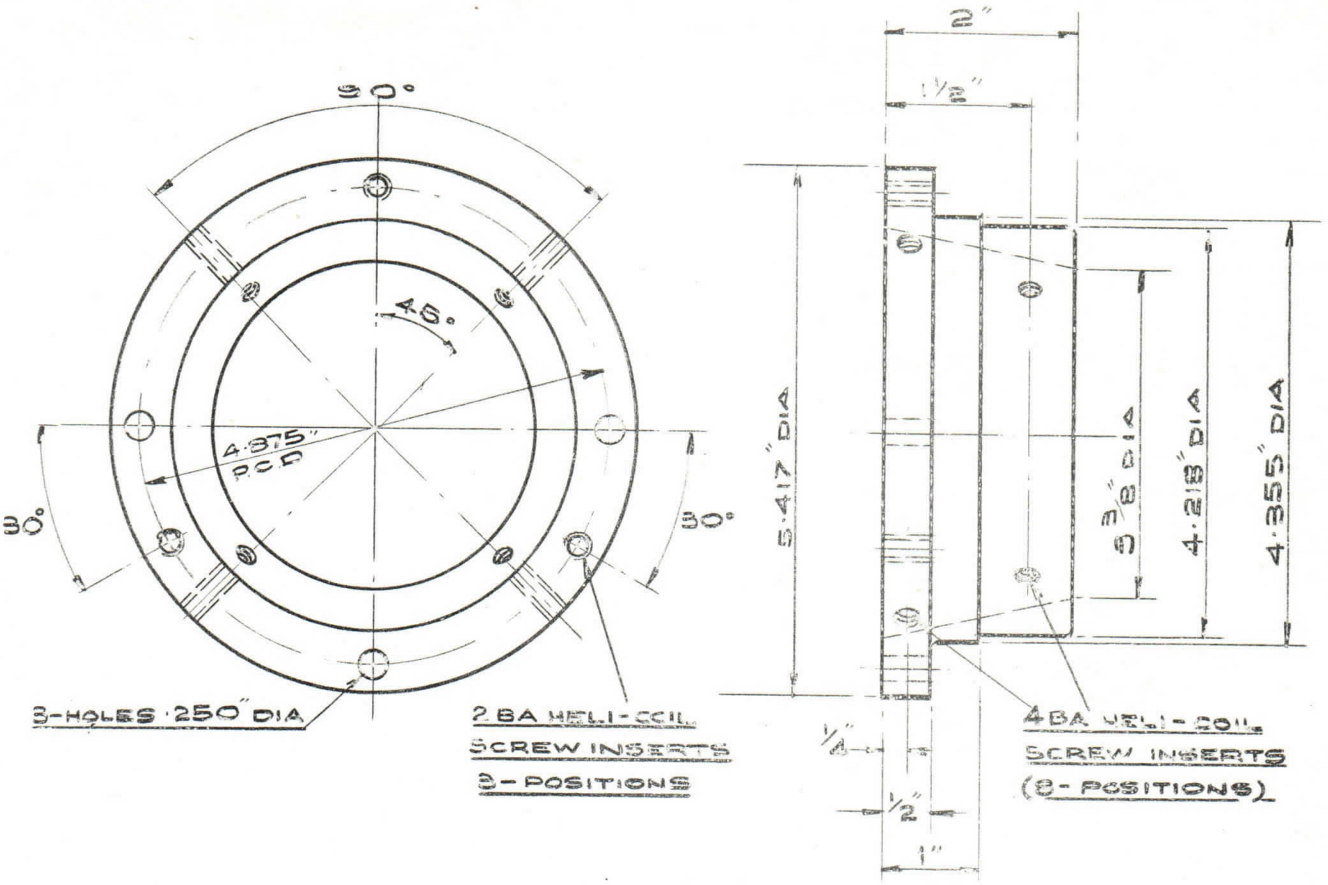
ES8/1086/10M/161/ 38187
Printed in England by Trendells Ltd., New Malden, Surrey.

TUBE MOUNTING RING



Angle between X & Y deflection axis : 90° ± 2°

Linear Writing speed for single transients : greater than 1400 cm/u secs.

P.D.A. Spiral resistance : 100 MΩ min. - 1,000 MΩ max.

Astigmatism Control : ± 20 V on A_3

Pattern Distortion : $^{+\ 0}_{-\ 50}$ V on A_4

CAPACITANCES

	Max.	Typical.
Modulator/all	10 pf	8 pf
Cathode / all	10 pf	6 pf
X_1/all excluding X_2	3.5 pf	3 pf
X_2/all excluding X_1	3.5 pf	3 pf
Y_1/all excluding Y_2	4 pf	3.5 pf
Y_2/all excluding Y_1	4 pf	3.5 pf
X_1/X_2	3 pf	2.5 pf
Y_1/Y_2	3.5 pf	3 pf

MOUNTING POSITION

The tube can be mounted by means of a collar attached to the tube at approximately the position of the centre of gravity. The collar is mounted so that a ground surface is parellel to and at a distance of 8.250" ± 0.003" from the apparent position of the phosphor plane as viewed from the tube face. Location holes in the collar are placed with respect to the X deflection axis to within ± 1°.

/continued ...

SHIELDING : Mu-metal shields are available which can be attached firmly to the collar.

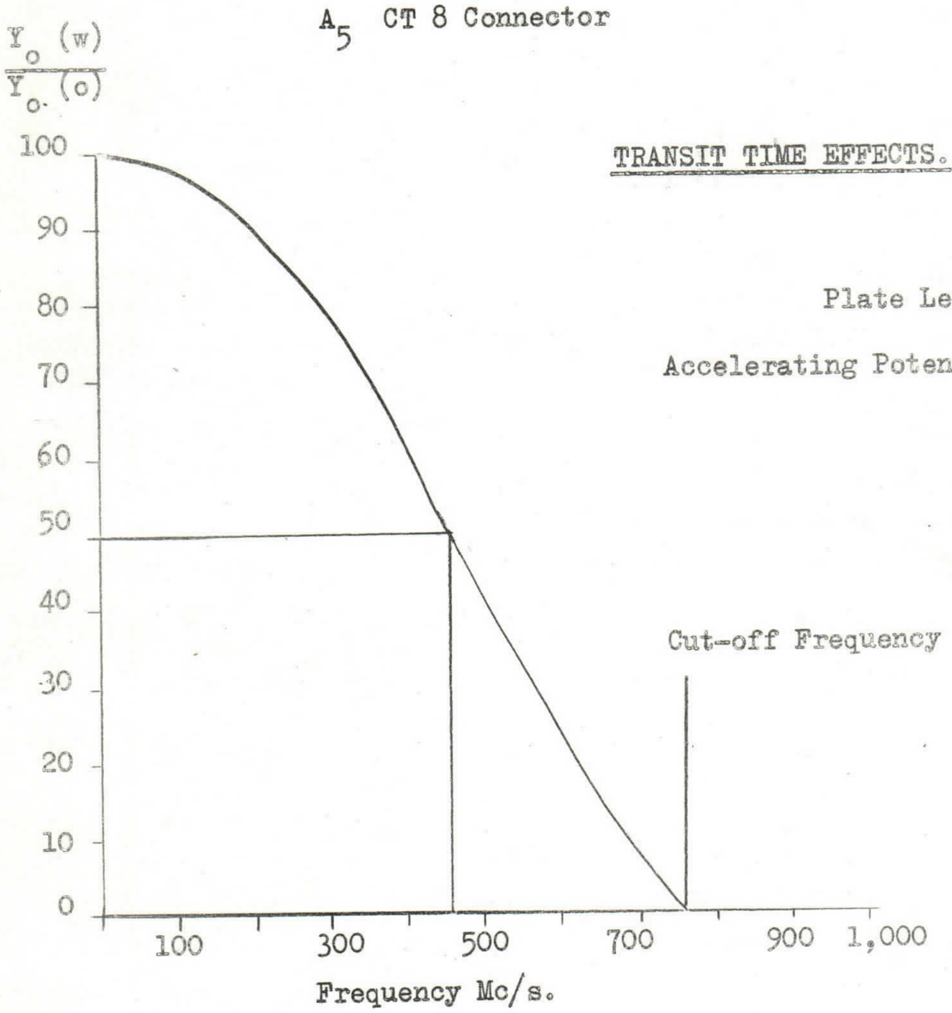
PIN CONNECTIONS : B7B Base.

Pin No.	1	2	3	4	5	6	7
Electrode	Cathode	Heater	A.1.	Modulator	N.C.	Focus A.2.	Heater.

Inter Plate shield and A.3. internally connected
X_1 X_2
Y_1 Y_2
} Side Pins

A_4 CT 8 Connector

A_5 CT 8 Connector



TRANSIT TIME EFFECTS.

Plate Length : 50 m.m.

Accelerating Potential : 4KV

$$\frac{Y_o\ (w)}{Y_o\ (o)} = \frac{\sin \frac{1}{2}\ wtr}{\frac{1}{2}\ wtr}$$

where Y_o (w) is the trace amplitude of a sine wave of frequency w
Y_o (o) " " " " " " " " " very low frequency
tr " " transit time of the electrons between the plates.

Cut-off frequency	760 Mc/s
50% value	460 Mc/s

EC8/7-R4
16.3.61.

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EMI CATHODE RAY TUBE TYPE MX51

The MX51 is a 5 inch (127 mm) high sensitivity, high brightness oscilloscope tube using post deflection acceleration.

CHARACTERISTICS

Mechanical	See drawing overleaf
Phosphor	Green sulphide, short peristence (EMI type GG3, equivalent to P.31)
Useful Scan	100 mm X by 60 mm Y

Electrical

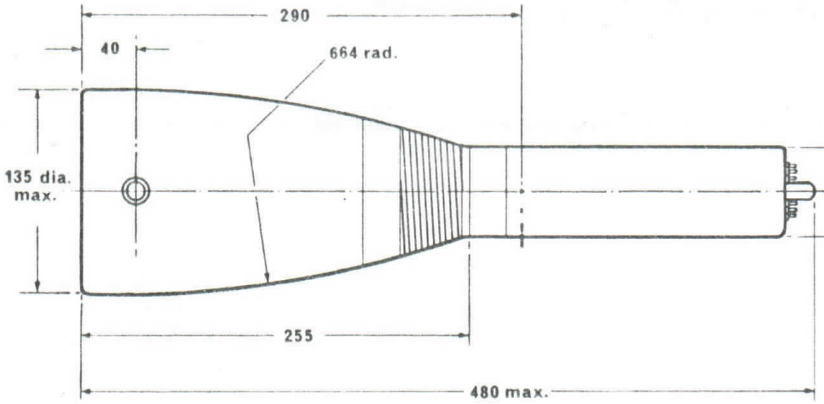
Ratings (All voltages are referred to cathode)		Standard	Max.
Heater voltage	V	6.3	-
A_1 voltage	kV	1.5	2.0
A_2 voltage	V	350	500
A_3 voltage	kV	1.5	2.0
A_4 (IPS) voltage	kV	1.5	2.0
A_5 (PDA) voltage	kV	12.0	15.0
PDA ratio to A_3		-	10:1
XPS voltage	V	A_3	A_3 + 50
PDS voltage with respect to XPS	V	-15	-30

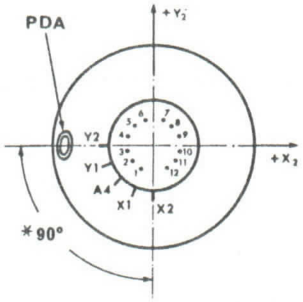
Operation - Under standard voltage conditions			Min.	Nominal	Max.
Heater current		A	0.50	0.55	0.60
Modulator voltage for visual cut-off		V	-45	-65	-85
X - sensitivity		mm/V	0.80	0.90	1.05
Y - sensitivity		mm/V	2.25	2.75	3.45
Inter-electrode capacitances	Modulator to all	pF	-	8.0	-
	Cathode to all	pF	-	6.0	-
	$X_{1,2}$ to all bar $X_{2,1}$	pF	-	6.0	-
	$Y_{1,2}$ to all bar $Y_{2,1}$	pF	-	3.6	-
	$X_{1,2}$ to $X_{2,1}$	pF	-	2.5	-
	$Y_{1,2}$ to $Y_{2,1}$	pF	-	1.5	-
	X_1+X_2 to Y_1+Y_2	pF	-	0.25	-
Spot diameter at 1 cd.*		mm	-	0.6	-
Spot deviation +		mm	-	-	15

* This is equivalent to an average line brightness of 80 ft-L for a raster of 100 lines x 60 mm long.

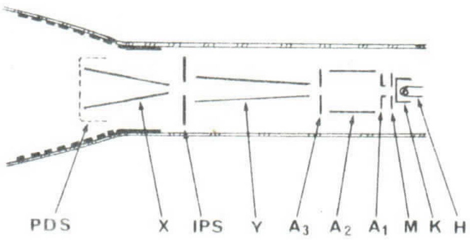
\+ The deviation of an unfocussed spot measured from the centre of the screen.

EMI CATHODE RAY TUBE TYPE MX51 (continued)





*between X2 and Y2 pins - other pins equally spaced



Mesh screen is connected to a potential of -15 V with respect to X-plate shield in order to suppress secondary electrons which could spoil contrast.

All dimensions are nominal and in millimetres except where otherwise stated. The MILLIMETRE dimensions are derived from the original INCH dimensions.

CONNECTIONS

Base Type B12F

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12
Electrode	M	K	H	H	A_2	IC	A_1	A_3	PDS	IC	XPS	IC

Side contacts
PDA Anode button type C.T.8 }
Deflection plated X_1, X_2, Y_1, Y_2 } See diagram above
A_4 (IPS) }

Symbols
A_1, A_2, A_3, A_4 = Anodes
H = Heater
IC = Internally connected
IPS = Inter-plate shield
K = Cathode

M = Modulator or grid
PDA = Post deflection accelerator anode
PDS = Post deflection screen (mesh)
XPS = X-plate shield

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EMI CATHODE RAY TUBE TYPE MX57

(Provisional Data)

The MX57 is a magnetically focused, magnetically deflected cathode ray tube intended for use in Film Scanning equipment. The tube face is of special, non-solarising glass and is optically ground for flatness and thickness. A green, very short afterglow phosphor is used; other phosphors of ultra-short afterglow are being developed.

CHARACTERISTICS

Mechanical

Overall length	532 mm nominal.
Neck diameter	36 mm maximum
Face diameter	185 mm nominal
Useful screen area	100 mm x 75 mm nominal
Deflection angle	42° double angle
Phosphor	Green (Zinc oxide) afterglow to one-tenth of initial value: 10^{-5} sec.

Electrical

			Maximum	Typical	Minimum
Heater voltage		V		4	
Heater current		A	1.1	1.0	0.8
Final anode voltage		kV	32	30	
Modulated cut-off voltage		V	-147	-117	- 87
Deviation of spot		mm	6		
Beam current		uA		300	
Line width at 100 uA		in	0.0055		
Capacitances	Grid to others	pF	12		
	Cathode to others	pF	10		

Connections

Base international octal   Side contact CT8

Pin No.	1	2	3	4	5	6	7	8
Electrode	Spark trap	Heater	-	-	Grid	-	Heater	Cathode

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EMI CATHODE RAY TUBE TYPE MX58

The MX58 is a 5 inch (127 mm) high sensitivity, high brightness oscilloscope tube using post deflection acceleration.

CHARACTERISTICS

Mechanical See drawing overleaf

Phosphor Green sulphide, short peristence (EMI type GG3, equivalent to P.31)

Useful scan 100 mm X by 60 mm Y

Electrical

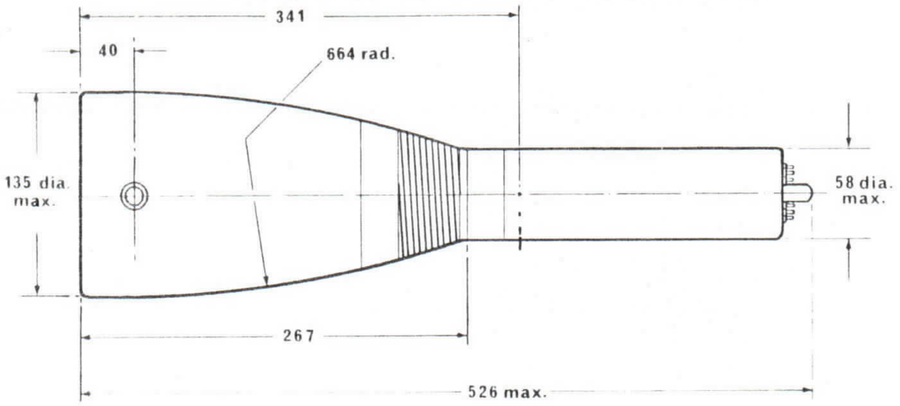
Ratings (All voltages are referred to cathode)		Standard	Max.
Heater voltage	V	6.3	-
A_1 voltage	kV	1.5	1.8
A_2 voltage	V	375	500
A_3 voltage	kV	1.5	3.3
A_4 (IPS) voltage	kV	1.5	3.3
A_5 (PDA) voltage	kV	15	17
PDA ratio to A		-	10:1
XPS voltage	V	A_3	A_3+50
PDS voltage with respect to XPS	V	-15	-30

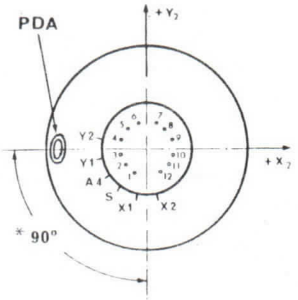
Operation - Under standard voltage conditions			Min.	Nominal	Max.
Heater current		A	0.50	0.55	0.60
Modulator voltage for visual cut-off		V	-45	-65	-85
X - sensitivity		mm/V	-	0.90	-
Y - sensitivity		mm/V	-	3.40	-
Inter-electrode capacitances	Modulator to all	pF	-	5.0	-
	Cathode to all	pF	-	3.6	-
	$X_{1,2}$ to all bar $X_{2,1}$	pF	-	5.5	-
	$Y_{1,2}$ to all bar $Y_{2,1}$	pF	-	3.4	-
	$X_{1,2}$ to $X_{2,1}$	pF	-	1.7	-
	$Y_{1,2}$ to $Y_{2,1}$	pF	-	1.7	-
	X_1+X_2 to Y_1+Y_2	pF	-	-	0.4
	$X_1+X_2+Y_1+Y_2$ to all	pF	-	-	0.1
Spot diameter at 1 cd.*		mm	-	0.6	-
Spot deviation +		mm	-	-	15

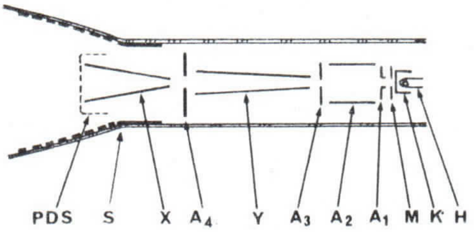
* This is equivalent to an average line brightness of 80 ft-L for a raster of 100 lines x 60 mm long.

\+ The deviation of an unfocussed spot measured from the centre of the screen.

EMI CATHODE RAY TUBE TYPE MX58 (continued)







Mesh screen is connected to a potential of -15 V
with respect to X-plate shield in order to suppress
secondary electrons which could spoil contrast

All dimensions are nominal and in millimetres except where otherwise stated.
The MILLIMETRE dimensions are derived from the original INCH dimensions.

CONNECTIONS

Base type B12F

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12
Electrode	M	K	H	H	A_2	NC	A_1	A_3	PDS	IC	XPS	NC

Side contacts
PDA Anode button type C.T.8 }
Deflection plates X_1, X_2, Y_1, Y_2 } See diagram above
A_4 (IPS) }

Symbols

A_1, A_2, A_3, A_4 = Anodes
H = Heater
IC = Internally connected
IPS = Inter-plate shield
K = Cathode
M = Modulator or grid
NC = No connection
PDA = Post deflection accelerator anode
PDS = Post deflection screen (mesh)
S = Spiral, externally connected to A_4
XPS = X-plate shield

EMI Electronics Ltd Valve Division

Hayes Middlesex England *(Controlled by Electric & Musical Industries Limited)*

Telephone: *Hayes 3888 Extension 2165* Cables: *Emidata, London* Telex: *London 22417*

Ref. 10772 CP

EMI

EMI ELECTRONICS LTD

Serving Science and Industry

VALVE DIVISION

TDX1 Cathode Ray Tube

Provisional Data

The TDX1 is a low voltage high resolution CRT with electromagnetic focus and electromagnetic deflection. With a usable screen diameter of 2 inches it is possible to display 1500 resolvable lines using only 5KV final anode potential. The green phosphor is blemish free over a given area and is of minimum grain size so that the brightness variation along a scanned line does not vary by more than 10%.

Typical Operating Conditions

V_{Anode} 5KV
Cut-off voltage 15V-30V
Heater voltage 6.3V
Heater current 0.55V

These tubes can be supplied with an external collar which is located with respect to both the phosphor plane to facilitate easy setting up in an optical system and to the electron beam to facilitate easy setting up of the focus coil.

Physical Dimensions

Tube length 13"
Face diameter 2"
Neck diameter 24 mm

EMI Electronics Ltd Valve Division

HAYES MIDDLESEX ENGLAND *(Controlled by Electric and Musical Industries Ltd)*

Telephone: *Southall 2468* Cables: *Emidata, London.* Telex *London 22417*

Printed in England by E.M.I. Ltd.

EMI ELECTRONICS LTD

Serving Science and Industry

VALVE DIVISION

BINARY ENCODER

This cathode-ray device is designed to convert analogue signals to a digital form.

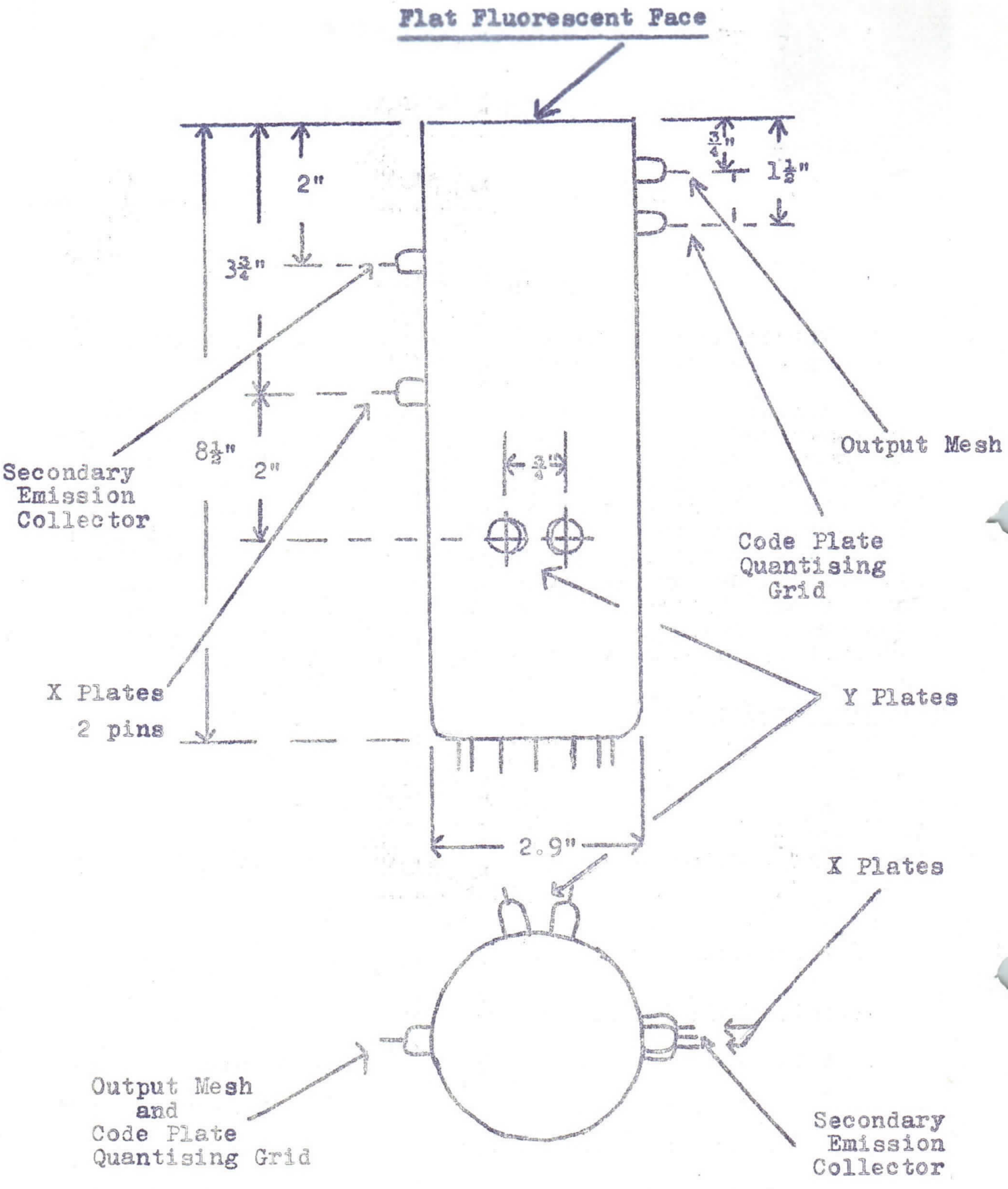
A conventional electron gun scans an electron beam across a code plate in which the apertures are so disposed as to produce the desired digital code (in particular, a 6-digit standard binary or the reflected binary code) on an output electrode placed behind the code plate. Provision is made to display the code as a series of dots on a flat face, the light from which can be used as the signal output and an amplified electrical signal produced from a suitably situated photomultiplier. Due to the extremely low output capacitance, signals are capable of being sampled at a frequency of up to 1 Mc/s.

Operating Conditions.

V_h	6.3 Volts
I_h	0.55 Amps
Grid Volts for cut-off	50-100 Volts
VA_1 A_3	2kV - 2.5kV
VA_2 Focus	200-500 Volts
Full Scale Deflection Voltage	
X Plates	90 V. peak to peak
Y Plates	100 V. peak to peak
Secondary emission collector	VA_3 + 300 Volts
Quantising Grid	VA_3 - 150 Volts
Code Plate	VA_3
Output Plate	VA_3 + 300 Volts
Base	B12G

Pin Connections

1	2	3	4	5	6	7	8	9	10	11	12
H	H	C	-	Code Plt	G	-	A_2	-	A_3	-	-



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Printed in England by E.M.I. Ltd.

Photocells

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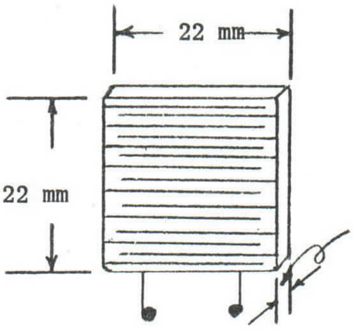
Serving Science and Industry

VALVE DIVISION

CADMIUM SELENIDE & CADMIUM SULPHIDE PHOTOCONDUCTIVE CELLS

Active area of cell
is 20 mm x 16 mm.



Thickness of cell:
2 mm

CHARACTERISTICS: (at 25°C)

	CdSe	CdS
Peak spectral response	7100 Å	5250 Å
Maximum Voltage *	120 V	120 V
Maximum continuous current * for longer than 5 seconds.	50 mA	60 mA
Maximum wattage dissipation for longer than 5 seconds.	¼ W	⅓ W
Maximum current - for less than 5 seconds	-	120 mA
Maximum wattage dissipation - for less than 5 seconds.	½ W	-
Dark current at 120 Volts	<2μA	<2μA

Photoconductive decay after excitation for a long period + to 2854°K Colour temp.

	CdS~~e~~		CdSe	
Excitation	decay to $^1/e$th	decay to $^1/_{10}$th	decay to $^1/e$th	decay to $^1/_{10}$th
1000 Lux	20 m sec.	100 m sec.	1.65 m sec.	6.0 m sec.
100 Lux	50 m sec.	250 m sec.	3.1 m sec.	13.5 m sec.
10 Lux	175 m sec.	> 1 sec.	10 m sec.	> 50 m sec.

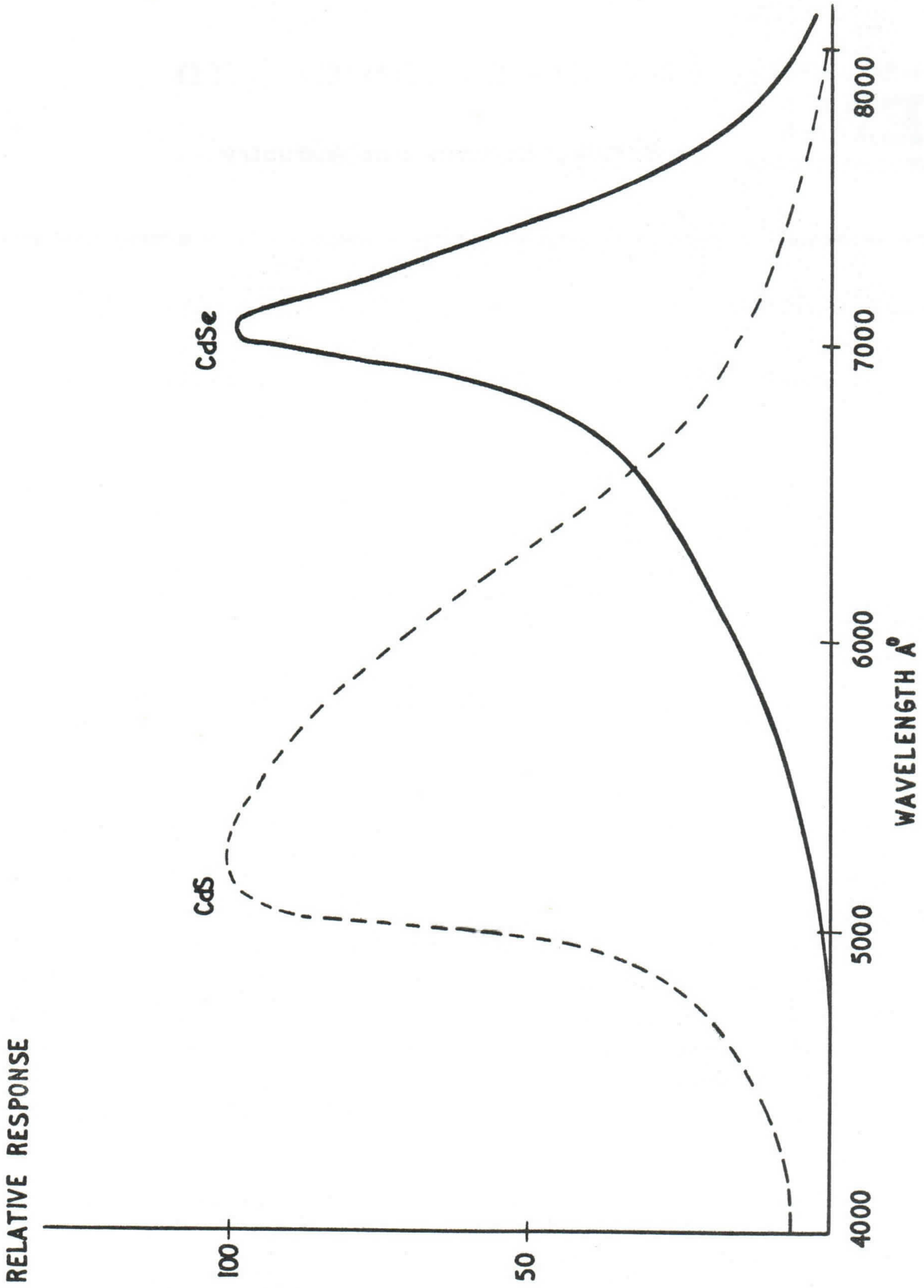
* Subject to Wattage Limitation

\+ A time greater than decay time to $^1/e$ th

EC8/48-1
7.11.60.

TD

TYPICAL SPECTRAL SENSITIVITY OF PHOTOCONDUCTIVE CELLS



EC8/48-2
7.11.60.

The Company reserves the right to modify these designs and specifications without notice

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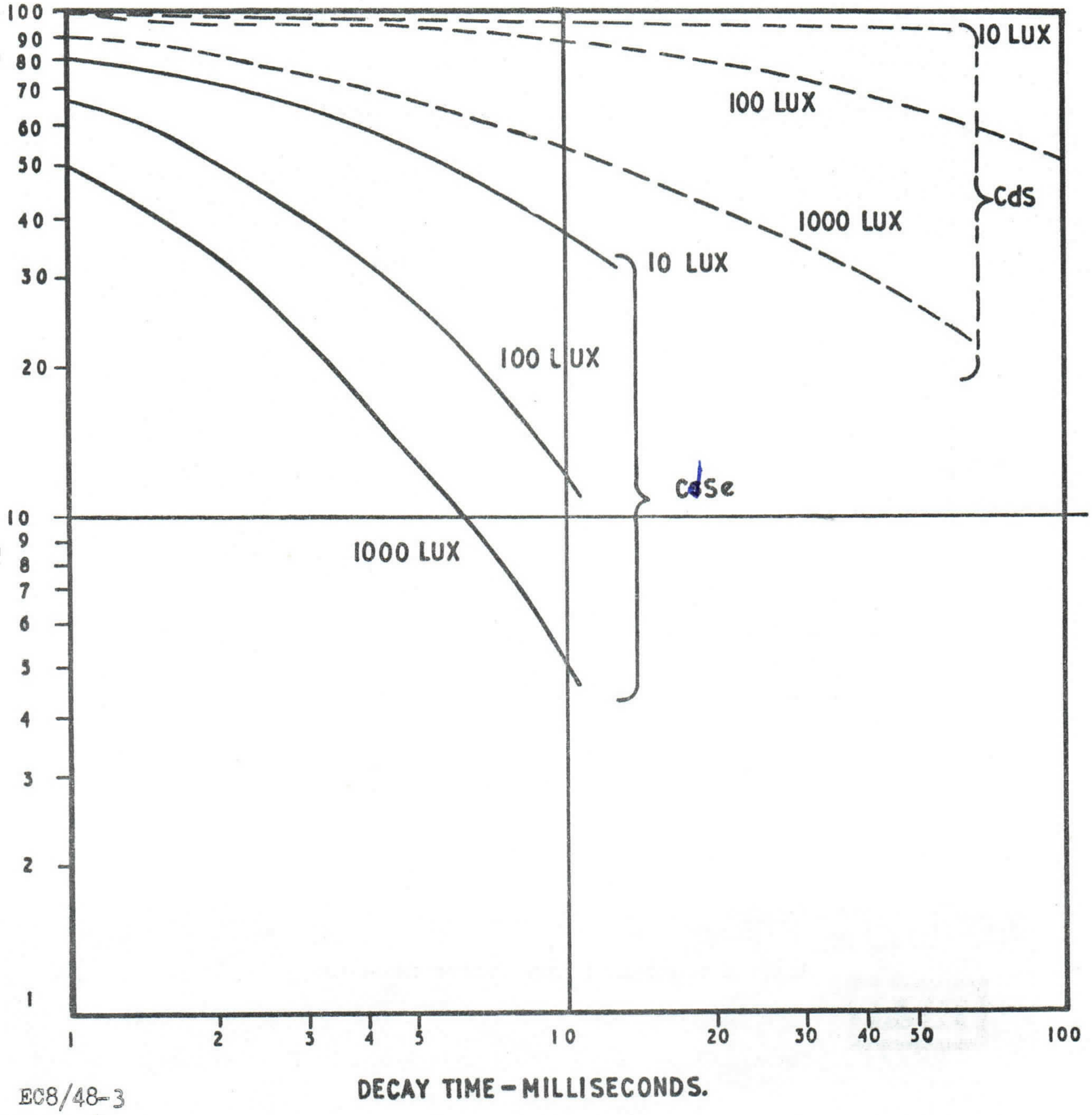
VALVE DIVISION

TYPICAL DECAY CHARACTERISTICS - CdS and CdSe CELLS

AMBIENT TEMPERATURE 25°C

EXCITATION PERIOD 2 MILLISECONDS

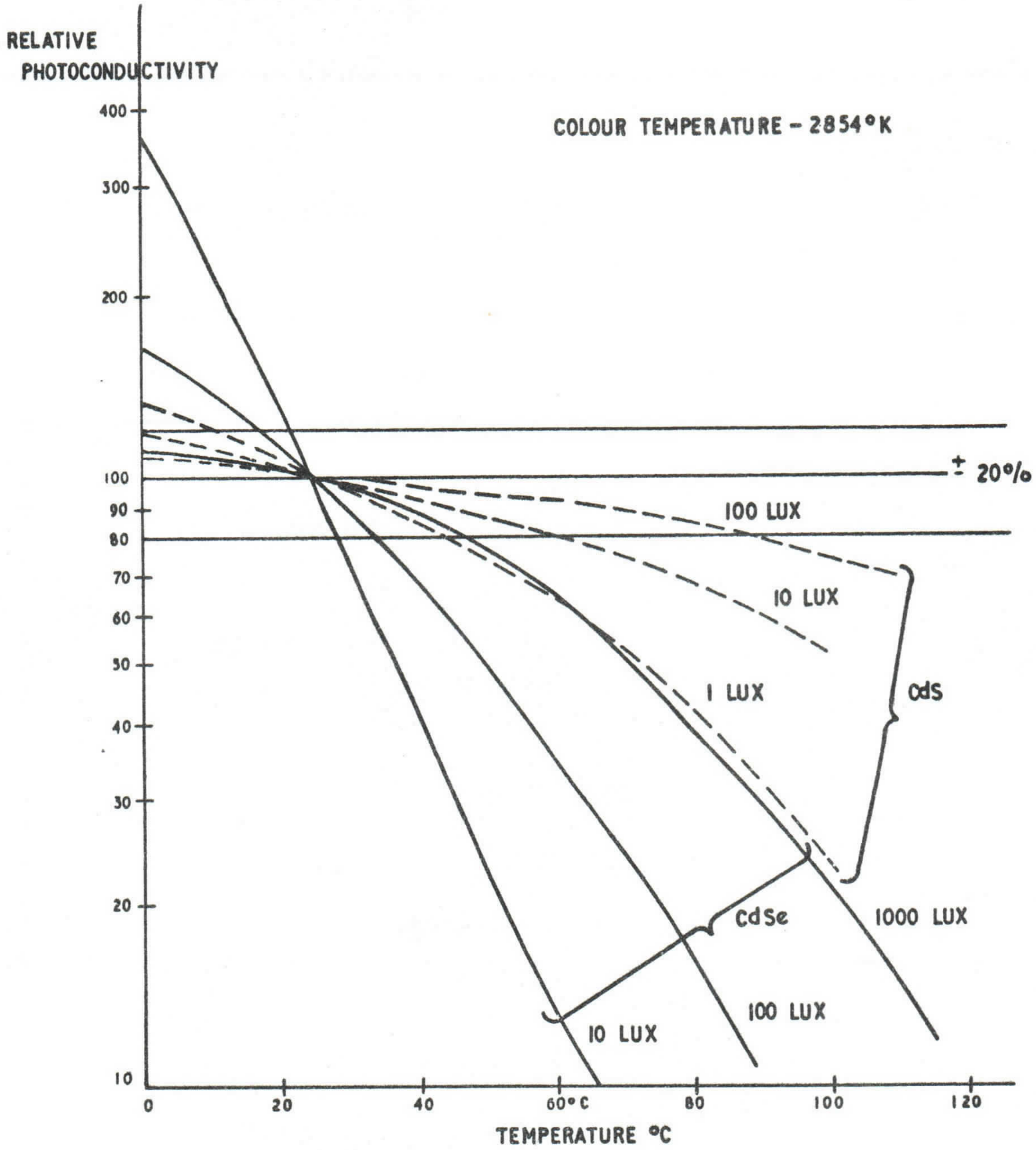
COLOUR TEMPERATURE 2854°K



TD

EC8/48-3
7.11.60

TYPICAL TEMPERATURE COEFFICIENT CdS AND CdSe CELLS



TD

EC8/48-4
7.11.60.

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EMI Electronics Ltd Valve Division

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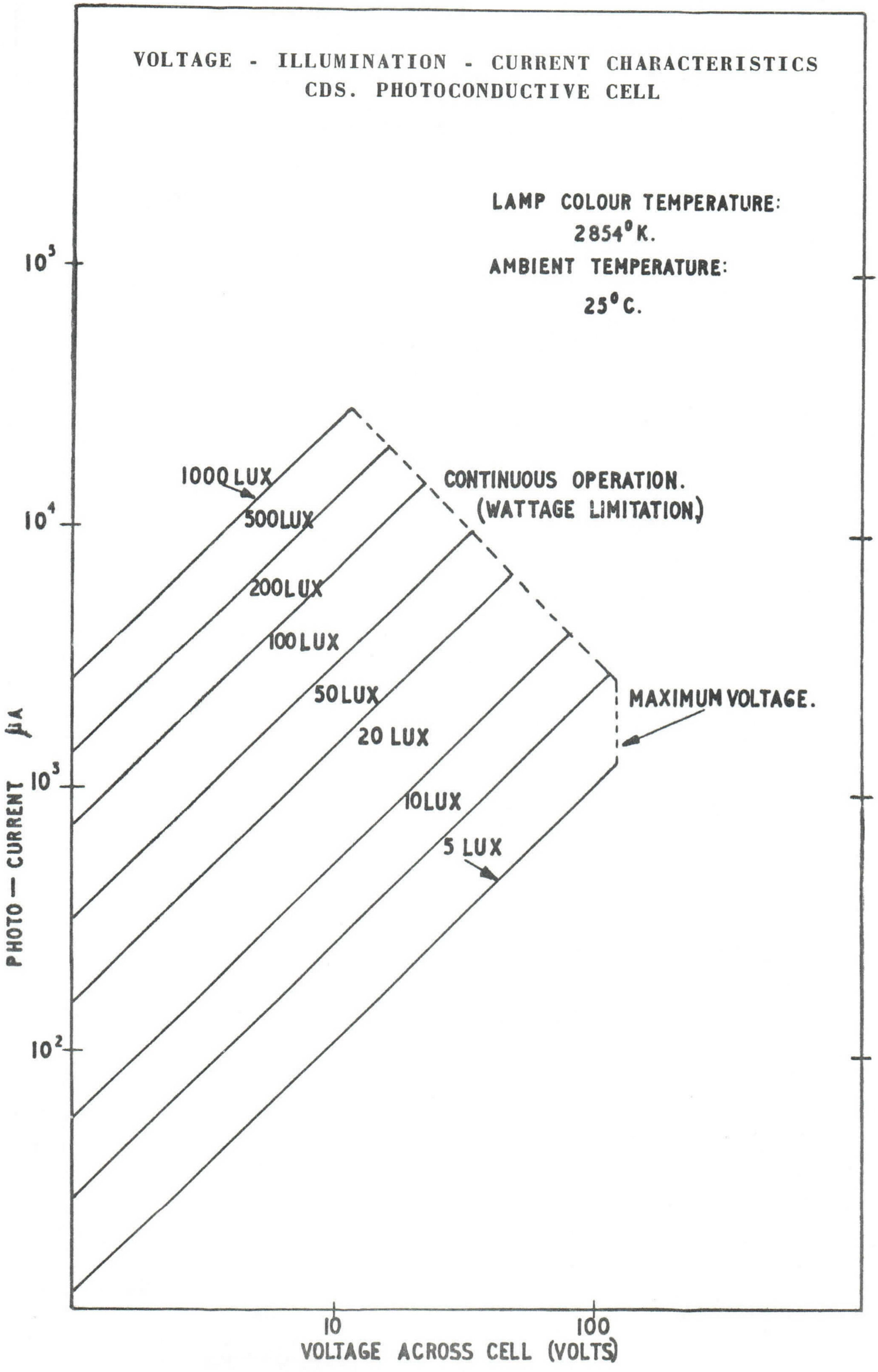
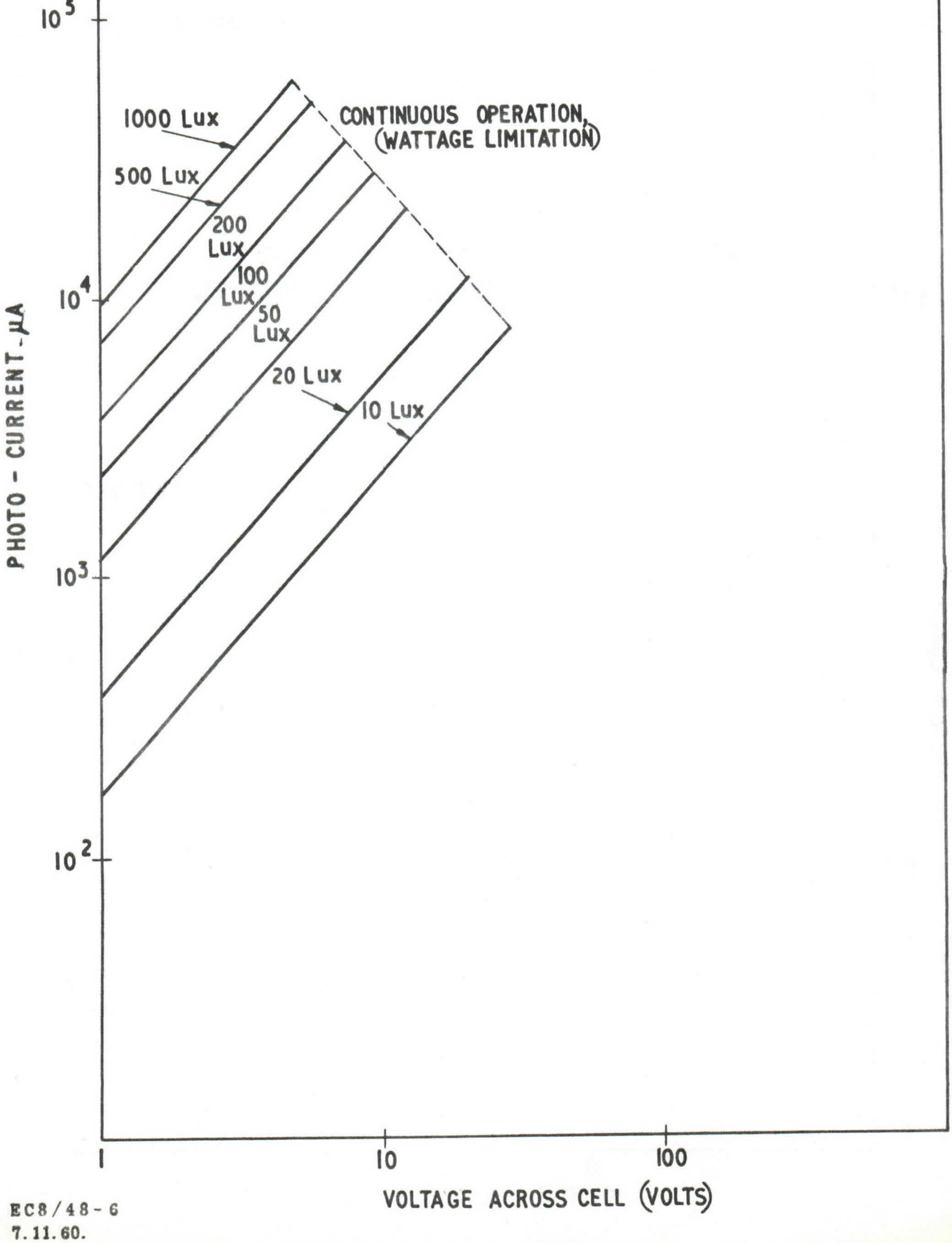


VOLTAGE - ILLUMINATION - CURRENT CHARACTERISTICS
CDS. PHOTOCONDUCTIVE CELL

VOLTAGE - ILLUMINATION - CURRENT CHARACTERISTICS

CdSe PHOTOCONDUCTIVE CELL

LAMP COLOUR TEMPERATURE:
2854° K



EC8/48-6
7.11.60.

EMI/US

file under EMI ⑤

TRAVELING WAVE TUBE
TYPE E107

EMI/US

EXECUTIVE OFFICES: 1750 North Vine St., Los Angeles 28, Calif. HO 2-4909
MANUFACTURING: 13259 Sherman Way, North Hollywood, California
EASTERN OFFICES: 50 Swalm St., Westbury (L.I.), New York. ED 4-5600

The E-107 is a one kilowatt, pulsed, S-Band traveling wave tube for use in broadband applications such as countermeasures systems and frequency scanning radars. Advanced metal-ceramic construction techniques enable this tube to withstand military airborne environments. The modern magnetic materials used in the periodic permanent magnetic focussing structure permit operation from —65 to 100° centigrade. An integral ion pump assures long service and shelf life. A grid for beam pulsing permits the use of a low power modulator.

PERFORMANCE CHARACTERISTICS:

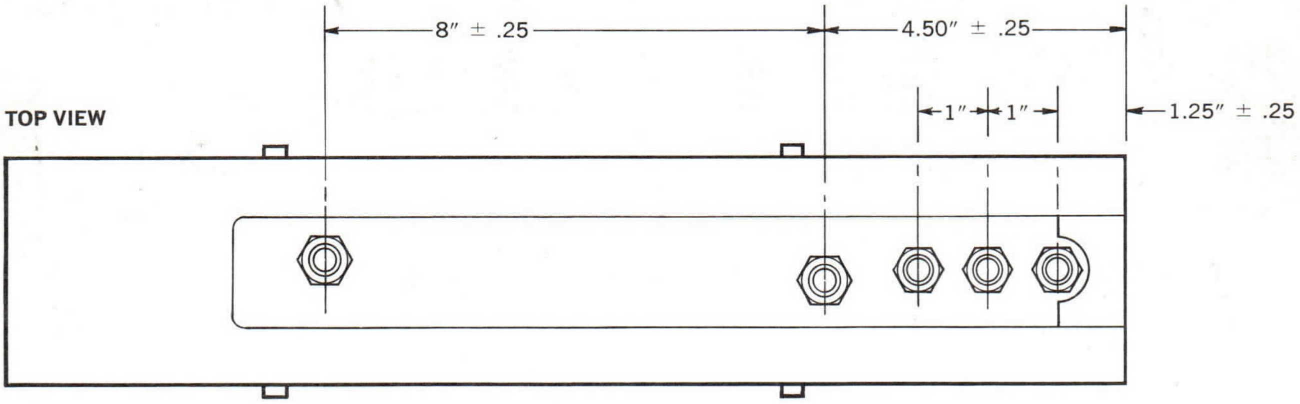
Frequency Range	2000 - 4000	mcs
Power Output (Min).	1000	watts
Gain (at 1 watt input)	30	db
Gain (at 50 mw input)	36	db
Duty Factor (Max.)	1	%

ELECTRICAL CHARACTERISTICS:

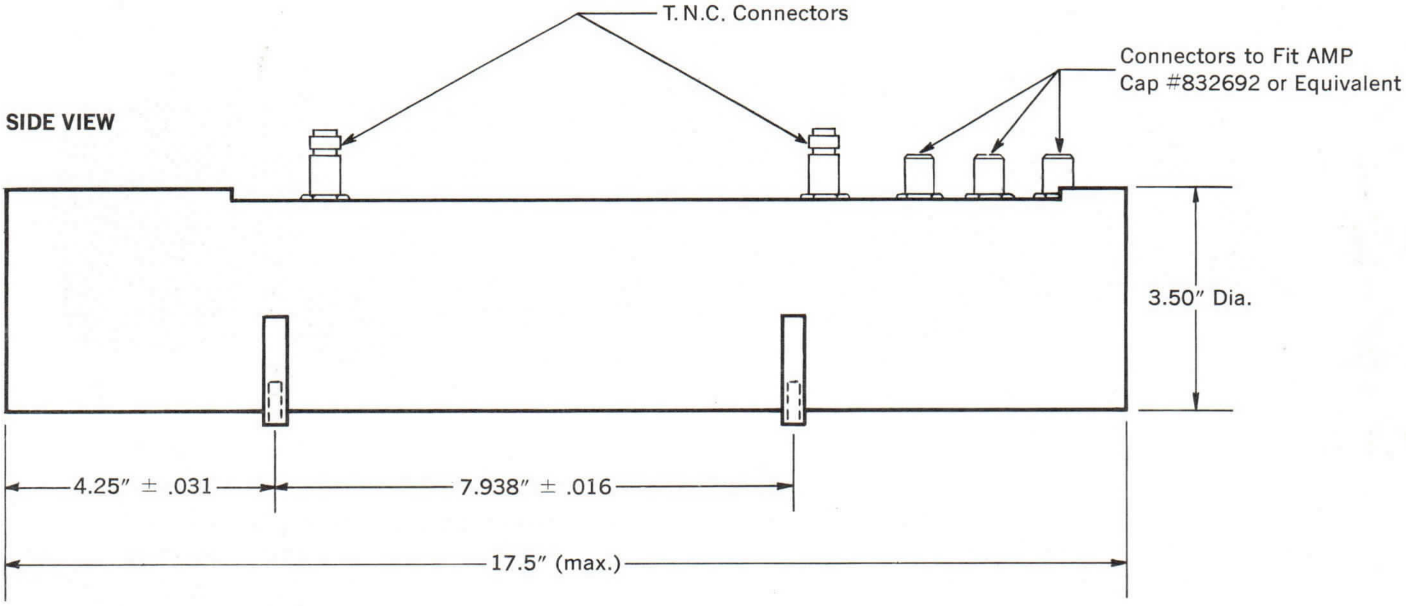
Heater	6.3	volts AC
Heater	3.0	Amps AC
Beam (Typical)	7000	Volts
Cathode (Peak)	1.3	Amps
Grid (Beam off)	—90	Volts
Grid (Beam on)	250	Volts
Grid capacity (to all other elements)	15	uuf

EMI/US reserves the right to modify the designs and specifications without notice.

TOP VIEW



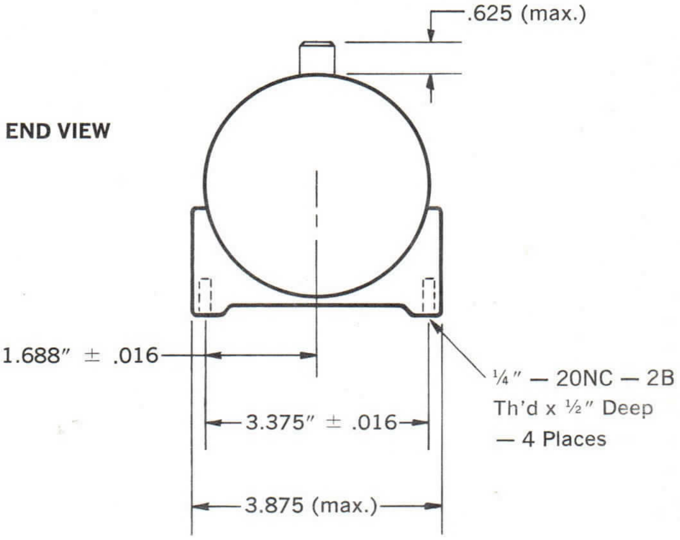
SIDE VIEW



TYPE E107

(with typical mounting brackets)

END VIEW



MECHANICAL CHARACTERISTICS:

Weight	10½ Lbs.
Cooling	75 cfm Forced Air
Mounting position	Any

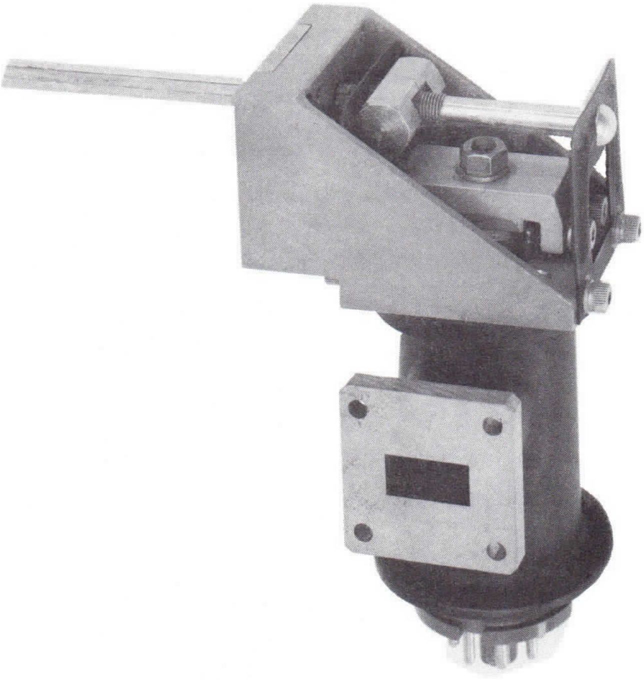
T.P.D

REFLEX KLYSTRON K_U-BAND

R9624
R9625
R9626

EMI / US

EXECUTIVE OFFICES: 1750 North Vine St., Los Angeles 28, Calif. HO 2-4909
MANUFACTURING: 13259 Sherman Way, North Hollywood, California
EASTERN OFFICES: 50 Swalm St., Westbury (L.I.), New York. ED 4-5600



These integral cavity reflex klystrons are designed for operation over a frequency range of 12 to 18 Kmc, with a minimum power output of 40 mw across the band.

EMI/US reflex klystrons have excellent frequency stability and long life, with low microphonics.

They are intended for application as local oscillators in radar and microwave receivers, and in microwave relay equipment. An important application is as pump tubes for parametric amplifiers. The long life and optimum electrical characteristics of these klystrons makes them ideally suited for use in test equipment.

The tubes have standard octal bases. RF output mates with a UG-419/U flange. Tube weight is approximately 1 lb. 6 oz.

OPERATION:

Maximum impedance of the reflector supply is 75,000 ohms.

A suitable diode should be connected directly between the reflector and cathode to avoid damage to the tube on positive swings of reflector potential.

The high voltage supply must never be applied to the resonator in the absence of negative reflector and grid potential. These tubes are normally operated with the resonator grounded, and the cathode should be preheated at normal heater voltage for a minimum period of one minute before voltage is applied to the resonator.

INSTALLATION:

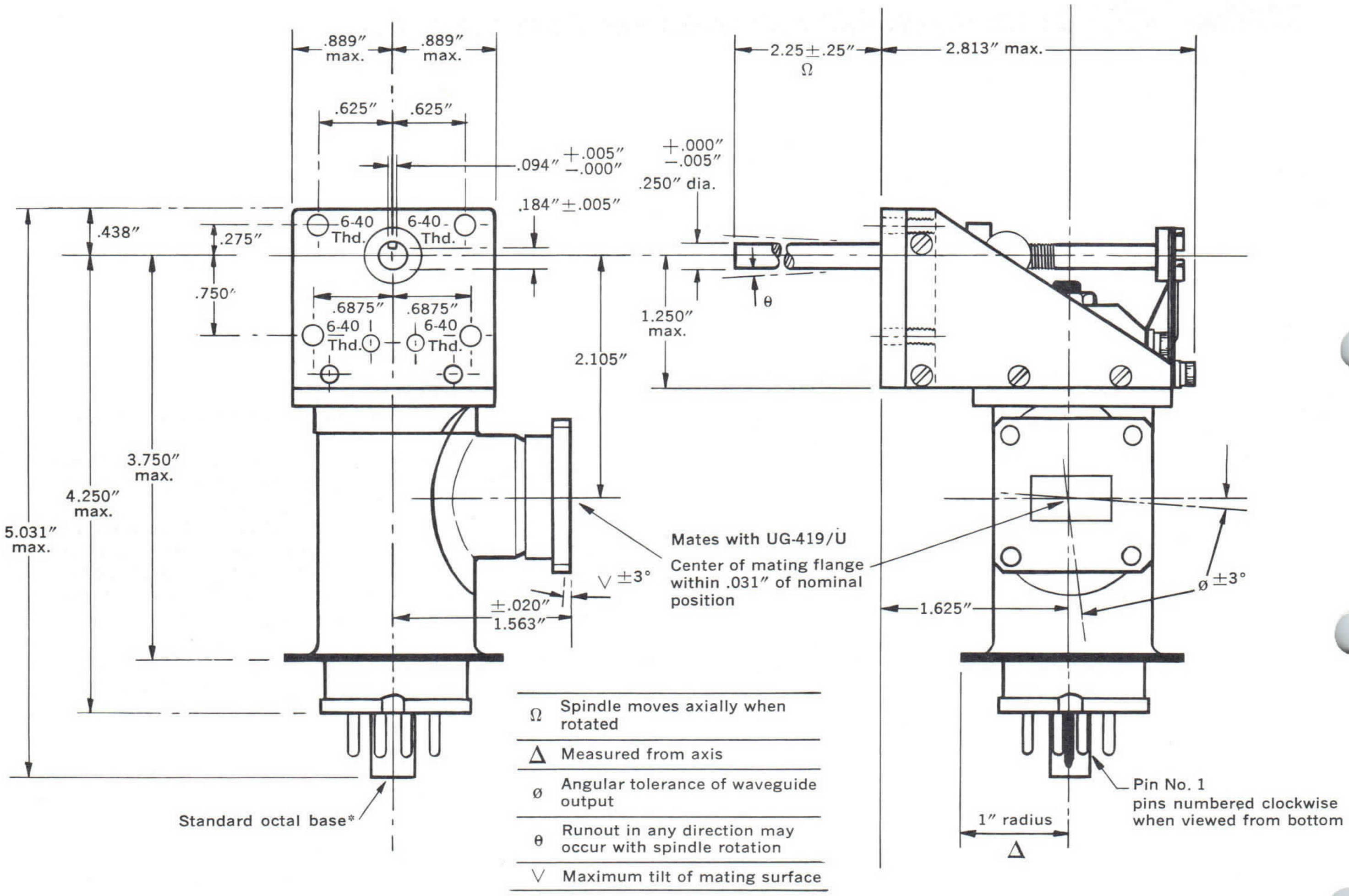
The tubes may be mounted in any position.

Temperature of the envelope should not be allowed to exceed 150°C at any point. Forced air cooling may be necessary if the klystron is used in a confined space.

ELECTRICAL CHARACTERISTICS:

		R9624	R9625	R9626
Frequency Range	Kmc	12-15	13.5-16.5	15-18
Electronic Tuning Range*	mc	40	40	40
Typical Power Output	mw	75	75	75
Minimum Power Output	mw	40	40	40
Beam Voltage	VDC	2000	2000	2000
Beam Current	ma	15	15	15
Reflector Voltage	VDC	−100 to −500	−100 to −500	−100 to −500
Reflector Current	μa	30	30	30
Heater Voltage	VDC	6.3	6.3	6.3
Heater Current	amps	0.8	0.8	0.8

*Note: The electronic tuning range is the frequency difference between half power points.



R9624
R9625
R9626

Notes:
*The standard octal base is within .125″ of nominal axis and has ±15° angular tolerance.
The tube is designed for use with a floating base socket.
Dimensions, unless otherwise indicated, give true geometric position.

Base Connections: IC = Internal Connection (Do Not Use)

Pin No.	1	2	3	4	5	6	7	8	Body
Electrode	Grid	Heater	IC	IC	Reflector	IC	Heater/ Cathode	IC	Resonator (Ground)

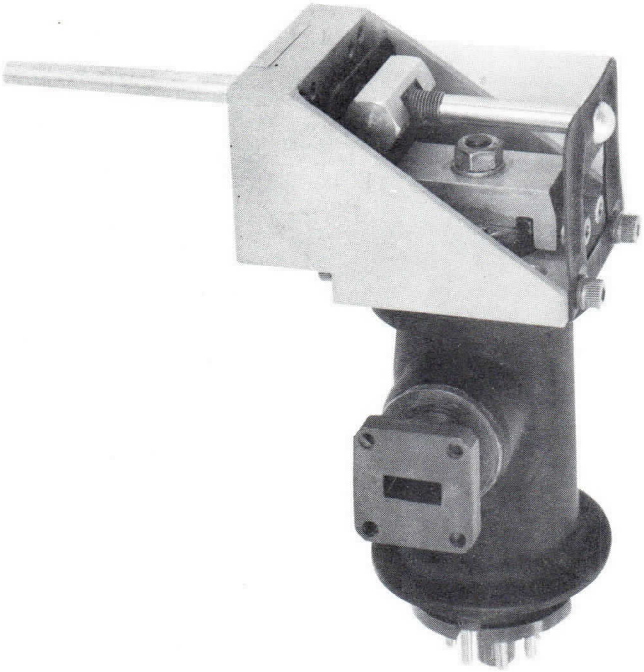
T.P.D.

EMI/US

EXECUTIVE OFFICES: 1750 North Vine St., Los Angeles 28, Calif. HO 2-4909
MANUFACTURING: 13259 Sherman Way, North Hollywood, California
EASTERN OFFICES: 50 Swalm St., Westbury (L.I.), New York. ED 4-5600

REFLEX KLYSTRON K-BAND

R9602
R9621
R9622



These integral cavity reflex klystrons are designed for operation over a frequency range of 18 to 26 Kmc, with a minimum power output of 40 mw across the band.

EMI/US reflex klystrons have excellent frequency stability and long life, with low microphonics.

They are intended for application as local oscillators in radar and microwave receivers. An important application is as pump tubes for parametric amplifiers. The long life and optimum electrical characteristics of these klystrons makes them ideally suited for use in test equipment.

The tubes have standard octal bases. RF output mates with a UG-595/U flange. Tube weight is approximately 1 lb. 6 oz.

OPERATION:

Maximum impedance of the reflector supply is 75,000 ohms.

A suitable diode should be connected directly between the reflector and cathode to avoid damage to the tube on positive swings of reflector potential.

The high voltage supply must never be applied to the resonator in the absence of negative reflector and grid potential. These tubes are normally operated with the resonator grounded, and the cathode should be preheated at normal heater voltage for a minimum period of one minute before voltage is applied to the resonator.

INSTALLATION:

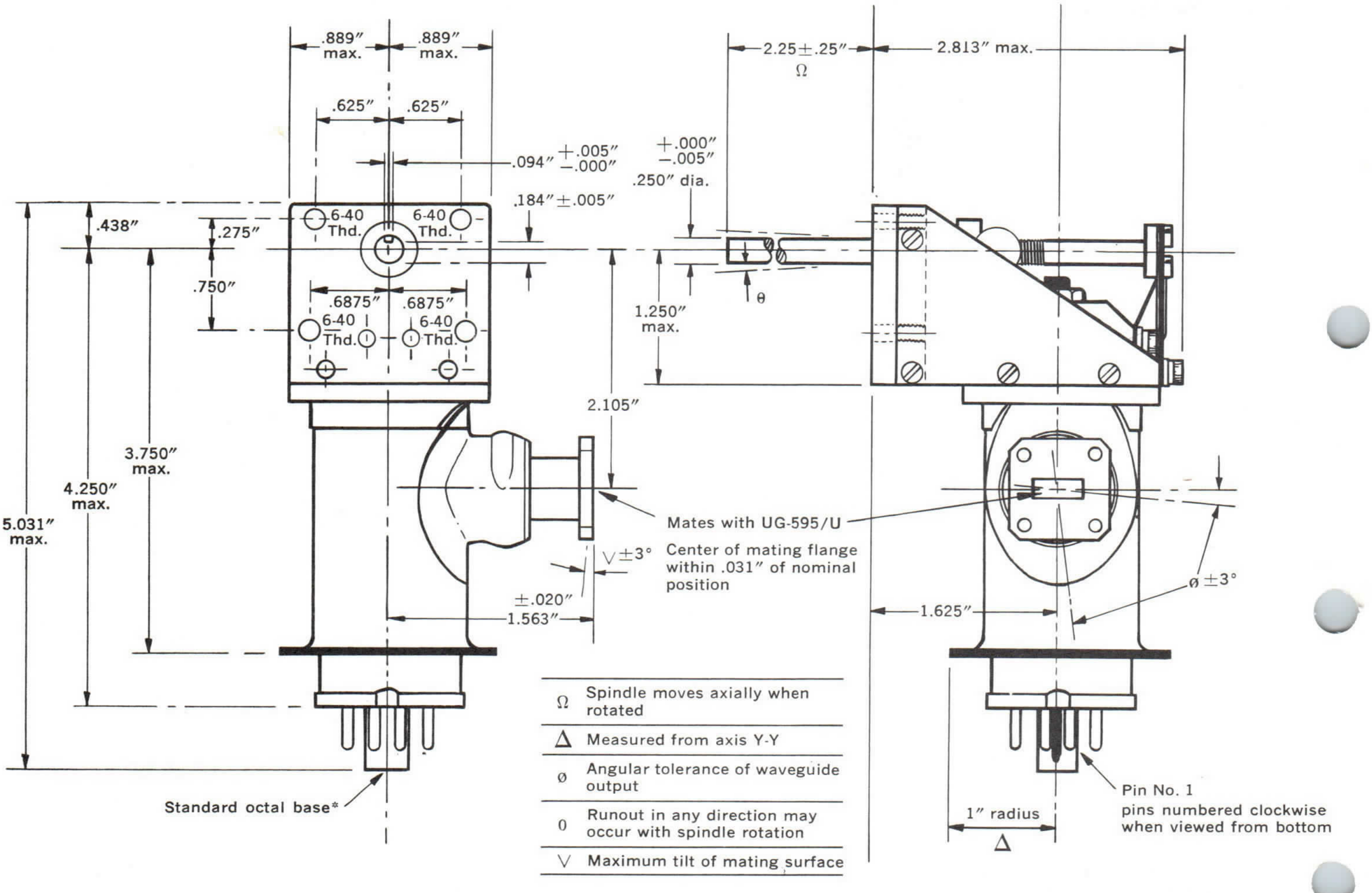
The tubes may be mounted in any position.

Temperature of the envelope should not be allowed to exceed 150°C at any point. Forced air cooling may be necessary if the klystron is used in a confined space.

ELECTRICAL CHARACTERISTICS:

		R9622	R9621	R9602
Frequency Range	Kmc	18-22.5	20-24	22.5-26
Electronic Tuning Range*	mc	40	40	40
Typical Power Output	mw	75	75	75
Minimum Power Output	mw	40	40	40
Beam Voltage	VDC	2000	2000	2000
Beam Current	ma	15	15	15
Reflector Voltage	VDC	—100 to —500	—100 to —500	—100 to —500
Reflector Current	μa	30	30	30
Heater Voltage	VDC	6.3	6.3	6.3
Heater Current	amps	0.8	0.8	0.8

*Note: The electronic tuning range is the frequency difference between half power points.



Ω	Spindle moves axially when rotated
Δ	Measured from axis Y-Y
ø	Angular tolerance of waveguide output
θ	Runout in any direction may occur with spindle rotation
V	Maximum tilt of mating surface

R9602
R9621
R9622

Notes:
*The standard octal base is within .125″ of nominal axis and has ±15° angular tolerance.
The tube is designed for use with a floating base socket.
Dimensions, unless otherwise indicated, give true geometric position.

Base Connections: IC = Internal Connection (Do Not Use)

Pin No.	1	2	3	4	5	6	7	8	Body
Electrode	Grid	Heater	IC	IC	Reflector	IC	Heater/ Cathode	IC	Resonator (Ground)

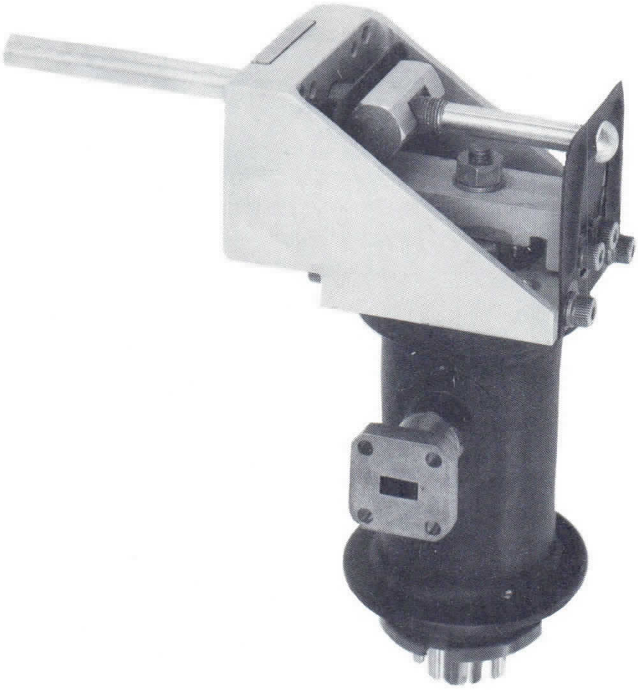
T.P.D

REFLEX KLYSTRON Ka-BAND

R9518
R9546
R9521

EMI/US

EXECUTIVE OFFICES: 1750 North Vine St., Los Angeles 28, Calif. HO 2-4909
MANUFACTURING: 13259 Sherman Way, North Hollywood, California
EASTERN OFFICES: 50 Swalm St., Westbury (L.I.), New York. ED 4-5600



These integral cavity reflex klystrons are designed for operation over a frequency range of 27 to 40 Kmc, with a minimum power output of 15 mw across the band.

EMI/US reflex klystrons have excellent frequency stability and long life, with low microphonics.

They are intended for application as local oscillators in radar and microwave receivers. An important application is as pump tubes for parametric amplifiers. The long life and optimum electrical characteristics of these klystrons makes them ideally suited for use in test equipment.

The tubes have standard octal bases. RF output mates with a UG-599/U flange. Tube weight is approximately 1 lb. 6 oz.

OPERATION:

Maximum impedance of the reflector supply is 75,000 ohms.

A suitable diode should be connected directly between the reflector and cathode to avoid damage to the tube on positive swings of reflector potential.

The high voltage supply must never be applied to the resonator in the absence of negative reflector and grid potential. These tubes are normally operated with the resonator grounded, and the cathode should be preheated at normal heater voltage for a minimum period of one minute before voltage is applied to the resonator.

INSTALLATION:

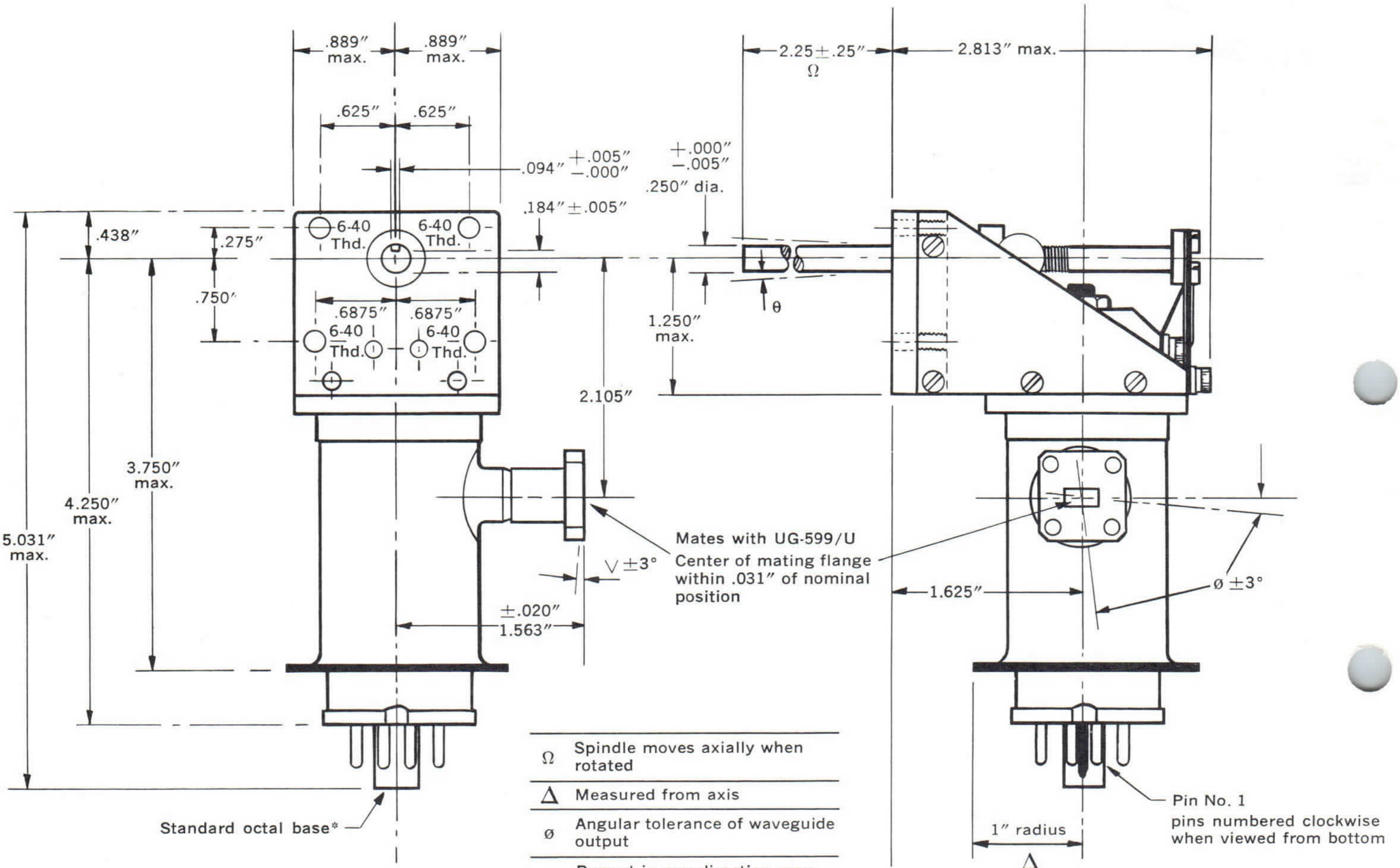
The tubes may be mounted in any position.

Temperature of the envelope should not be allowed to exceed 150°C at any point. Forced air cooling may be necessary if the klystron is used in a confined space.

ELECTRICAL CHARACTERISTICS:

		R9518	**R9546**	**R9521**
Frequency Range	Kmc	27.8-32.2	32-37.5	35-40
Electronic Tuning Range*	mc	60	60	60
Typical Power Output	mw	60	60	60
Minimum Power Output	mw	15	15	15
Beam Voltage	VDC	2000	2000	2000
Beam Current	ma	15	15	15
Reflector Voltage	VDC	−100 to −500	−100 to −500	−100 to −500
Reflector Current	μa	30	30	30
Heater Voltage	VDC	6.3	6.3	6.3
Heater Current	amps	0.8	0.8	0.8

*Note: The electronic tuning range is the frequency difference between half power points.



Ω	Spindle moves axially when rotated
Δ	Measured from axis
ø	Angular tolerance of waveguide output
θ	Runout in any direction may occur with spindle rotation
V	Maximum tilt of mating surface

R9518
R9546
R9521

Notes:
*The standard octal base is within .125″ of nominal axis and has ±15° angular tolerance.
The tube is designed for use with a floating base socket.
Dimensions, unless otherwise indicated, give true geometric position.

Base Connections: IC = Internal Connection (Do Not Use)

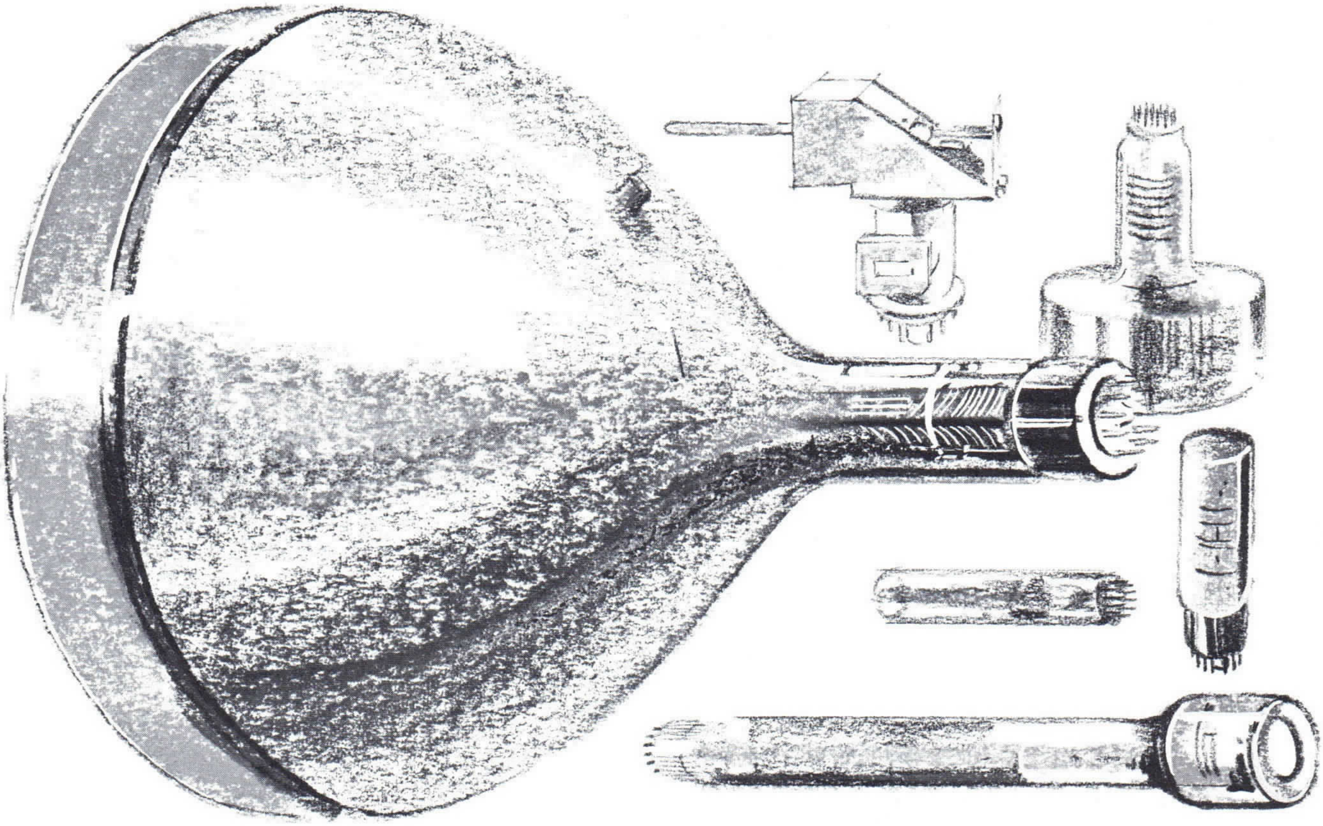
Pin No.	1	2	3	4	5	6	7	8	Body
Electrode	Grid	Heater	IC	IC	Reflector	IC	Heater/ Cathode	IC	Resonator (Ground)

T.P.D

CTP

EMI/US

ELECTRON TUBE DIVISION



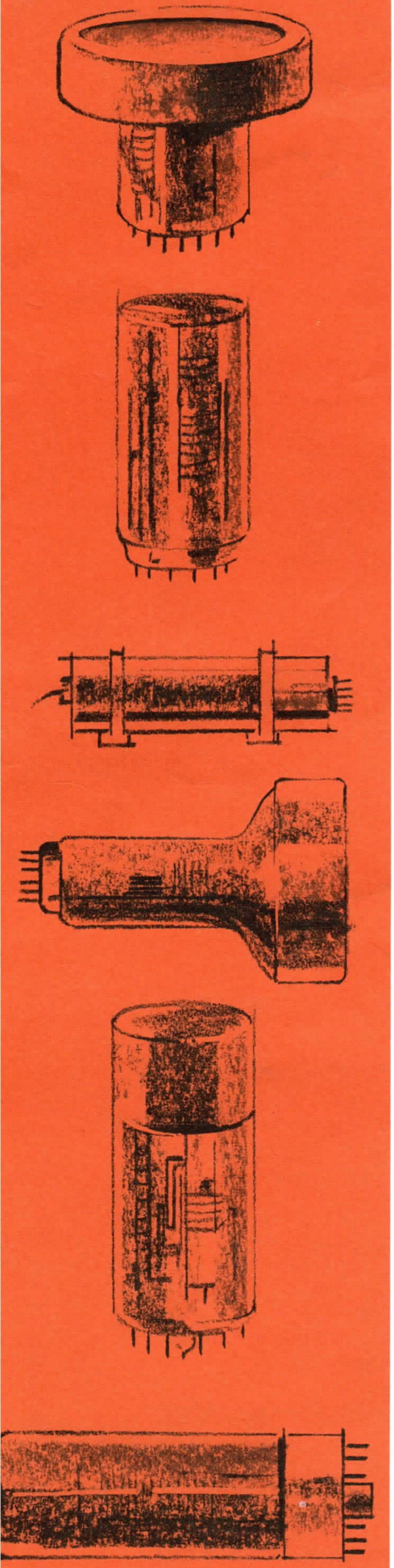
EMI/US Electron Tubes cover the spectrum

"from audio to ultraviolet"

The Electron Tube Division of EMI/US is backed by more than 20 years of experience in electronic tube design and manufacture, of leadership in producing the highest quality photomultiplier and television camera tubes, and in pioneering design and production of microwave tubes.

An EMI/US tube represents years of advanced research and development and the most modern, quality-controlled production techniques. At EMI/US, the emphasis is upon quality, performance, and service.

A national network of field sales offices and representatives has been established in principal cities across the country to provide information on a broad range of products. These products include photomultipliers and photocells, klystrons, magnetrons, traveling wave tubes and other microwave components, and a high resolution line of television camera tubes and cathode ray tubes.



C1

PHOTOMULTIPLIERS

EMI/US photomultiplier tubes meet the highest quality standards. They provide low dark current, low noise, excellent photocathode uniformity and highest sensitivity, and minimal gain shift with changes of input signal levels.

A complete line of photomultipliers from 1″ to 12″ is available in a broad spectral response range from ultraviolet to infrared. Glass and quartz tubes are available, with highly stable cesium-antimony or maximum sensitivity multi-alkali cathodes. All Electron Tube Division photomultipliers meet the highest standards for performance and long life.

PHOTOCELLS

KLYSTRONS

EMI/US klystrons have kept pace with the increasing demands for precision and high performance required of these microwave tubes, since their earliest development.

Millimeter Reflex Klystrons These advanced integral cavity tubes for the frequencies of 12-40 Kmc have a wide tuning range, optimum frequency stability, low microphonics, and long life with high power output.

Plug-In Klystrons and Cavities A line of plug-in klystrons for use with external cavities is produced in a frequency range from 1 to 12 Kmc. These plug-in units are designed for use with EMI/US external tunable cavities, and possess the same high performance and long life standards as all other EMI/US klystrons.

TRAVELING WAVE TUBES

These traveling wave tubes are small, lightweight, PPM focused, temperature compensated metal-ceramic tubes designed for severe airborne and space environments. Operating in the S-Band (2-4 Kmc), they are rated at 1 KW pulsed minimum power output.

MAGNETRONS

EMI/US packaged magnetrons are designed for pulse operation at frequencies from 9 to 80 Kmc, with excellent power output.

MICROWAVE COMPONENTS

TELEVISION CAMERA TUBES

Long experience in anticipating and meeting broadcast requirements has resulted in extremely high resolution tubes with superior sensitivity for broadcast and special application use. The line includes 4½″ image orthicons, C.P.S. orthicons, and improved, high performance vidicons with infrared and ultraviolet response, for studio, remote, film pick-up and industrial applications.

CATHODE RAY AND STORAGE TUBES

A wide range of cathode ray tubes includes radar, oscilloscope and special type tubes for a broad number of applications. Special tube types include color projection tubes, flying spot scanners, ribbon beam recording tubes and special storage and recording tubes.

CORONA STABILIZERS

A line of standard and high voltage gas discharge stabilizers provide a stabilized voltage over the ranges from .35 to 7 KV; for use as general purpose references, for stabilizing the focusing and accelerating potential of CRT's, and for stabilizing Geiger counter or photomultiplier supplies.

SPECIAL SERVICES

A staff of experienced application engineers is on hand at both the Eastern and Western field offices of the Electron Tube Division. These specialists will be happy to help you with individual problems. They are no further away than your telephone.

CUSTOM TUBES

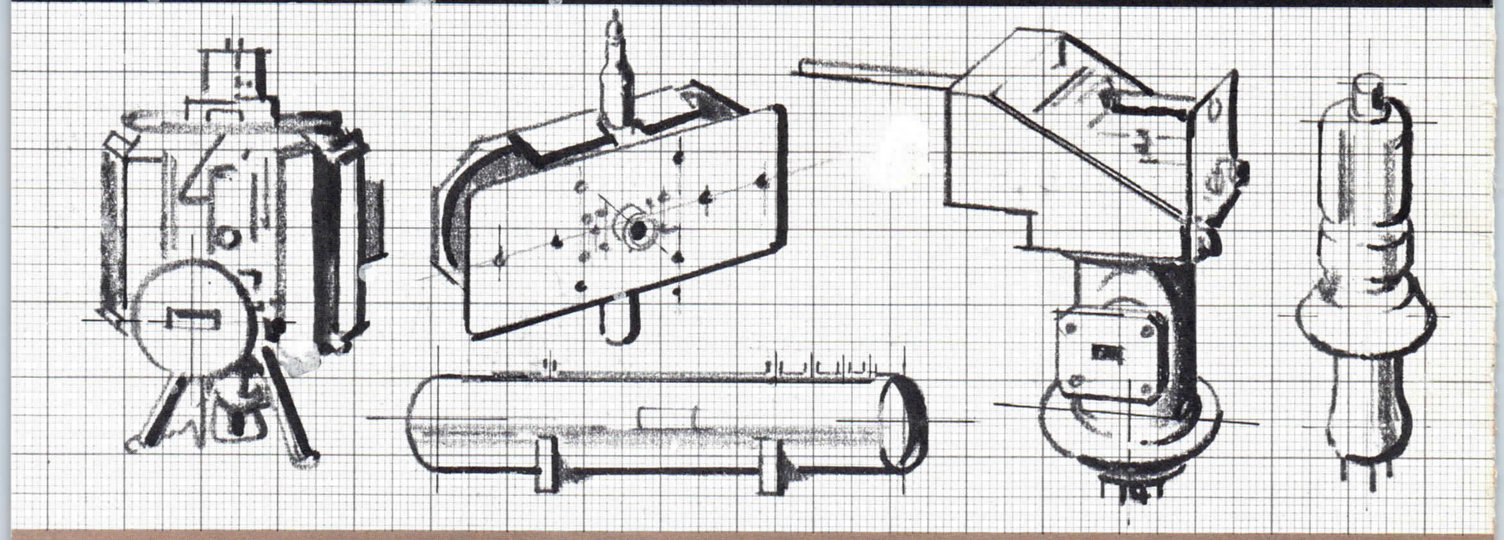
If you require a special tube, inquire about it. Many of the tubes the Electron Tube Division makes may be modified to meet your requirements, or a custom tube may be designed for your specific application.

EMI/US ELECTRON TUBE DIVISION

Executive Offices: 1750 North Vine St., Los Angeles 28, Calif. HO 2-4909
Field Sales Offices: 50 Swalm St., Westbury (L.I.) New York ED 4-5600
Manufacturing Facilities: 13259 Sherman Way, North Hollywood, Calif. PO 4-6200

EMI/US

MICROWAVE TUBE CATALOG T-2



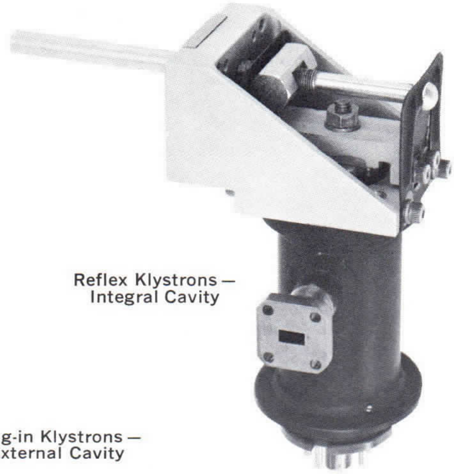
REFLEX KLYSTRONS
MULTIPLE CAVITY KLYSTRONS
MAGNETRONS
TRAVELING WAVE TUBES

AT EMI/US, THE EMPHASIS IS UPON QUALITY, PERFORMANCE AND SERVICE

✓

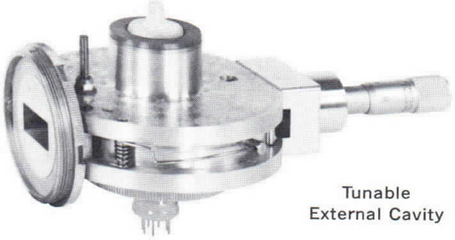
EMI/US MICROWAVE TUBE CATALOG T-2

EMI/US

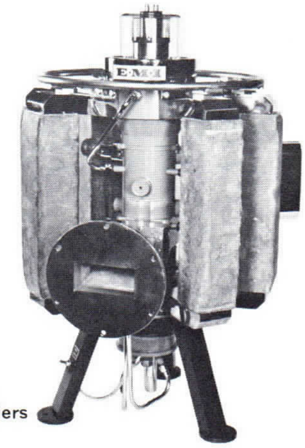


Reflex Klystrons — Integral Cavity

Plug-in Klystrons — External Cavity

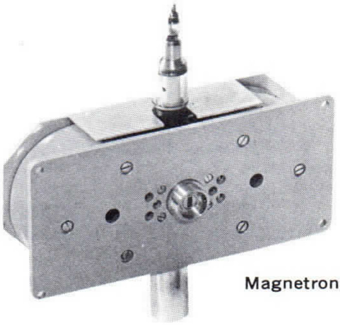


Tunable External Cavity



Multi-Cavity Klystron Amplifiers

Traveling Wave Tubes



Magnetrons

REFLEX KLYSTRONS — Integral cavity

TUBE	FREQUENCY RANGE (kmc/s)	ELECTRONIC TUNING RANGE Between – 3 db* (mc/s)	POWER OUTPUT MIN – TYP (mw)	
R5146+	34.2-35.58	70	30 mw	90 mw
R6010	4.4-4.8	35	3 watts	3.5 watt
R6015	4.27-4.76	10	30 mw	150 mw
R9516	7.05-7.3	15	1.8 watt	3 watt
R9518+	27.8-32.2	70	15 mw	80 mw
R9651+	31.25-33.7	70	15 mw	60 mw
R9521+	35-40	70	15 mw	60 mw
R9546+	32-37.5	70	15 mw	60 mw
R9547+	25-27.7	70	15 mw	80 mw
R9602+	22.5-26	40	40 mw	80 mw
R9621+	20-24	40	40 mw	80 mw
R9622+	18-22.5	40	40 mw	80 mw
R9624	12-15	40	40 mw	100 mw
R9625	13.5-16.5	40	40 mw	100 mw
R9626	15-18	40	40 mw	100 mw

PLUG-IN KLYSTRONS‡ — External cavity†

TUBE	FREQUENCY RANGE (kmc/s)	ELECTRONIC TUNING RANGE Between – 3 db* (mc/s)	POWER OUTPUT MIN – TYP (mw)	
R5222	4-12	15	25	45
CV2346	4-12	15	30	45
R9559	1-5.4	35	100	150
RK6112A	1-5	20	100	150

MULTI-CAVITY KLYSTRON AMPLIFIERS††

TUBE	FREQUENCY RANGE (kmc/s)	NUMBER OF CAVITIES	DUTY FACTOR
R9571	2.7-3	4	.005

TRAVELING WAVE TUBES + +

TUBE	FREQUENCY RANGE (kmc/s)	MAX DUTY FACTOR	SMALL SIGNAL GAIN (db)
E107	2-4	.01	36
E112	2-4	.01	36
E114	2.8-3.5	.01	36
E115	2.9-3.1	.02	36
E121	2.5-4	.01	36

MAGNETRONS

TUBE	FREQUENCY (kmc/s)	PEAK POWER OUTPUT MIN (kw)
R9509	16.2-17.2	50
R9515	34.5-35.3	35
R6138	34.5-35.3	15

*Electronic tuning range is measured between half-power points for reflex klystrons. Electronic tuning range of plug-in klystrons is dependent upon the external cavity used.

**Measured with respect to cathode.

‡Ruggedized versions of external cavity reflex klystrons are available to meet adverse environmental conditions.

†Tunable and fixed-frequency external cavities are available for EMI/US plug-in klystrons.

MICROWAVE TUBES

BEAM VOLTAGE (v)	BEAM CURRENT MAX (ma)	REFLECTOR VOLTAGE (neg. v)**	HEATER VOLTAGE (v)	HEATER CURRENT (amps)	RF CONNECTORS	BASE	REFLECTOR Between 3db Points Typical (v)
2000	15	100-500	6.3	.8	Waveguide	Octal	37
750	150	150-550	6.3	.8	Coax	Octal	110
300	75	50-250	6.3	.8	Coax	Octal	50
1000	120	200-550	12.6	1.25	Waveguide	Octal	60
2000	15	100-500	6.3	.8	Waveguide	Octal	44
2000	15	100-500	6.3	.8	Waveguide	Octal	40
2000	15	100-500	6.3	.8	Waveguide	Octal	30
2000	15	100-500	6.3	.8	Waveguide	Octal	34
2000	15	100-500	6.3	.8	Waveguide	Octal	51
2000	15	100-650	6.3	.8	Waveguide	Octal	55
2000	15	100-650	6.3	.8	Waveguide	Octal	55
2000	15	100-650	6.3	.8	Waveguide	Octal	55
2000	15	100-650	6.3	.8	Waveguide	Octal	60
2000	15	100-650	6.3	.8	Waveguide	Octal	60
2000	15	100-650	6.3	.8	Waveguide	Octal	60

BEAM VOLTAGE (v)	BEAM CURRENT MAX (ma)	REFLECTOR VOLTAGE (neg. v)**	HEATER VOLTAGE (v)	HEATER CURRENT (amps)	RF CONNECTORS	BASE
300	50	50-500	6.3	.8	—	Min 7 Pin
300	50	50-500	6.3	.8	—	Min 7 Pin
300	35	70-500	6.3	1.2	—	4 Pin
250	34	55-350	6.3	.7	—	Min 7 Pin

PEAK POWER OUTPUT (kw)	PEAK BEAM VOLTAGE (kv)	INPUT POWER (w)	FOCUSING	COOLING	GAIN AT SATURATION (db)	BANDWIDTH AT 27 db· GAIN (mc)
150	50	900	P.M.	Water	44	45

SATURATED GAIN (db)	POWER OUTPUT MIN (watts)	CATHODE CURRENT PEAK (ma)	GRID VOLTAGE (Beam On) (v)	BEAM VOLTAGE (kv)	FOCUSING	COOLING	DIMENSION (inches)	RF CONNECTORS
30	1000	1300	200	7	PPM	Air	17.5″ L x 3″ D	Coax
30	1000	1500	No Grid	7	PPM	Air	17.5″ L x 3″ D	Coax
33	2000	1300	200	7	PPM	Air	17.5″ L x 3″ D	Coax
30	1000	1300	No Grid	7	PPM	Air	17.5″ L x 3″ D	Coax
33	1000	1500	200	7	PPM	Air	17.5″ L x 3″ D	Coax

TYPICAL DUTY CYCLE	PEAK ANODE VOLTAGE MAX (kv)	PEAK ANODE CURRENT MAX (amps)	MAX. PULSE WIDTH (μ sec.)	HEATER STARTING CURRENT (amps @ 6.3v)	COOLING	DIMENSIONS (inches)
.00075	16	30	1.	7.5	Air	7½″ x 9″ x 3″ OA
.0004	16	25	.5	5	Air	8⅜″ x 10½″ x 2¼″ OA
.0004	14	13	.5	3	Air	8⅜″ x 10½″ x 2¼″ OA

††Classified models of multiple-cavity klystrons are also available from EMI/US.

+Rugged construction of these EMI/US reflex klystrons permits them to meet the vibration and temperature specifications of MIL-E-5400D, Class II. These tubes may be supplied to meet high altitude conditions upon special order.

++EMI/US Traveling Wave Tubes have a rugged metal-ceramic construction which enables them to successfully withstand the environmental conditions specified in MIL-E-5400D, Class II, with no degradation in performance.

EMI/US reserves the right to modify the designs and specifications without notice.

File under EMI Item ④

EMI/US products are backed by more than 20 years of experience in electronic tube design and manufacture, including original pioneering work in microwave components and equipment. EMI/US specializes in the production of highest quality microwave tubes to the most exacting standards.

EMI/US microwave tubes provide extreme reliability, long life and constant characteristics.

A national network of field sales offices and representatives has been established in principal cities across the country to provide you with specialized assistance. Inquire about other precision EMI/US electron tubes: Photomultiplier tubes, television camera tubes and cathode ray tubes.

REFLEX KLYSTRONS

The broad line of EMI/US reflex klystrons offers reliable, consistent operation, excellent frequency stability, long life and superior noise characteristics. These tubes are intended for application as local oscillators in radar and microwave receivers, and in low power transmission equipment such as microwave relay links. An important application is their use as power stabilized pump sources for parametric amplifiers.

The long life and optimum electrical characteristics of these klystrons makes them ideally suited for use in signal generators and laboratory test equipment. Internal cavity, external cavity and plug-in types are included in the line. Ruggedized versions of certain tubes are available to meet extreme environmental conditions. Tunable and fixed-frequency cavities for use with plug-in klystrons may be ordered from EMI/US.

MULTIPLE CAVITY KLYSTRON AMPLIFIERS

These high gain, multiple cavity klystron amplifiers feature excellent reliability. These tubes are suggested for radar applications, where a high output, ruggedly constructed klystron is required.

MAGNETRONS

EMI/US magnetrons are suitable for aircraft or missile beacon, radar, and telementry applications. They feature extended life with excellent reliability.

TRAVELING WAVE TUBES

EMI/US traveling wave tubes are inherently rugged metal-ceramic type tubes which provide superior performance over a wide range of environmental extremes. They are wide-band, high gain tubes, recommended for radar and ECM applications.

ADVERSE ENVIRONMENTS

EMI/US microwave tubes are available for adverse environmental operation, where frequency stability is required during operation under a wide range of dynamic conditions. Many of these tubes are suitable for use in airborne radar, missile and space probe applications. Special rugged tubes may be supplied to meet other adverse environments by EMI/US engineers.

APPLICATION ENGINEERING

A highly qualified staff of application engineers is available to provide assistance in your design or performance problems. The broad range of EMI/US microwave products makes it possible for these experienced engineers to suggest stock tubes for a majority of applications. If, however, special performance is required, they will be happy to work with you to design a specific tube to meet your requirements.

EMI/US

Headquarters: 1750 N. Vine St., Los Angeles 28, Calif., HO 2-4909
Manufacturing: 13259 Sherman Way, North Hollywood, California
Eastern Office: 151 West 46th Street, New York 36, N.Y., CI 5-1216

SAMPLE MONITORS

EMI

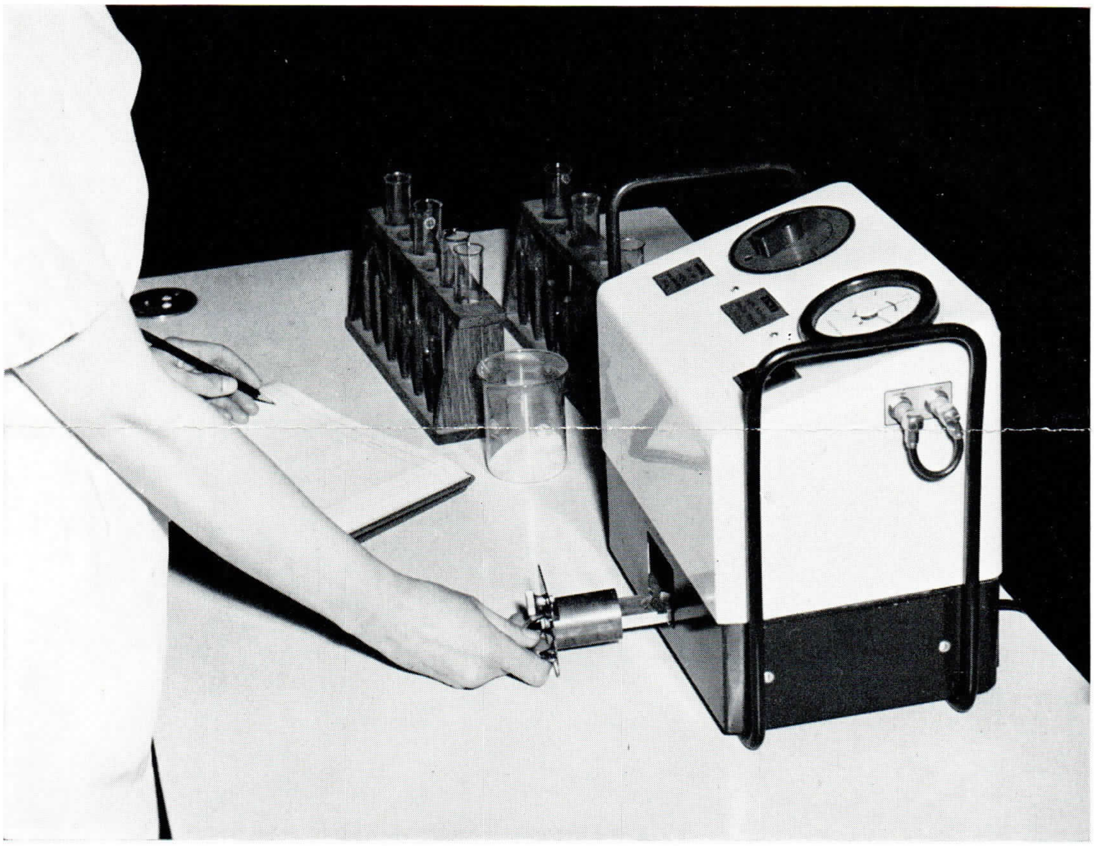
EMI ELECTRONICS LTD

Serving Science and Industry

INSTRUMENT DIVISION

LOW ACTIVITY SAMPLE MONITOR

Type SM1



THE Low Activity Sample Monitor, one of the EMI range of nuclear health instruments, incorporates the most up-to-date transistor circuits and a lead shield to form a compact and transportable counting system.

Important features of this unit are:—

- ★ **Transistor circuitry is used throughout for reliability and low power consumption.**
- ★ **A thin end window G.M. tube allows low energy beta counting.**
- ★ **The built-in lead shield cuts down background.**
- ★ **It is compact and transportable.**
- ★ **It can be battery operated for field use, or**
- ★ **Mains operated for laboratory use.**
- ★ **It can be used with suitable probes for bench monitoring.**

The Low Activity Sample Monitor is a self-contained instrument designed to determine the activity of small samples of radioactive material, and it will respond to beta energies down to the order of 140 KeV. The efficiency for Carbon 14 samples is approximately 20%.

The instrument is battery, or supply mains, operated (220V or 110V 50/60 c/s) and contains a 1½ inch wall lead castle with a suitable drawer assembly for the insertion of samples. The counter output is available for scaling when the required e.h.t. is provided. Transistors are used throughout and the circuit is arranged on easily serviced printed boards.

The readings are indicated by a double-range linear ratemeter providing sensitivities of 0–50 and 0–500 counts per second, and by a four decade, electromechanical register, which can be manually reset, usable for up to 5 counts per second. The natural background is less than 20 counts per minute. The ratemeter may be used with standard probes for monitoring purposes.

SPECIFICATION

Range:	0—500 counts per second, 0–50 counts per second
Display:	Electromechanical register (4 decades); 3 inch 270° linear scale meter
Natural Background Count:	<20 counts per minute
Integrating Time:	6 sec approx.
Dead Time:	150 μ sec
G. M. Tube:	EW 3 H (End window 1·5–2·5 mg/cm^2) Cathode diam. 24mm
Planchet Size:	¾in or 1in (2 cm or 2·5 cm)
Battery Check:	Switch positions are provided which allow batteries to be checked on load by the meter.
Temperature Range:	The equipment will operate satisfactorily in ambient temperatures between 0°C and 45°C.
E.H.T. Available at Probe Socket:	850 volts to 1650 volts into 66 Megohms, approximately.
Dimensions:	Width 16in (41 cm) Height 11½ in (29 cm) Depth 8 in (20·6 cm)
Weight:	60 lb (27 Kg)
Power Requirements:	(1) 12 off 1½ V cells (RAY-O-VAC 2 LP or equivalent U2 type) or (2) 190/250V 50/60 c/s 90/130V 50/60 c/s

ACCESSORIES

The following EMI probes can be used with the SM1:

Alpha types AP2 and AP3, Beta/Gamma types BP3, BP4 and GP2.

EMI

E M I Electronics Ltd Instrument Division

Hayes Middlesex England *(Controlled by Electric & Musical Industries Limited)*

Telephone: *Hayes 3888 Extension 2223* Cables: *Emidata, London* Telex: *London 22417*

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Geiger-Müller Tubes

EMI

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Serving Science and Industry

EMI

VALVE DIVISION

GEIGER-MÜLLER TUBES

ORGANICALLY QUENCHED TYPES

✓ EHM2S GM4 ✓
✓ 2B2 2B7 ✓
✓ XA1 G150 ✓

E.M.I. markets a range of thin-window counter tubes specially designed for the detection of beta particles, but also suitable for gamma and X-rays.

Apart from the thin end windows, which are necessarily fragile, the tubes are of rugged all-metal construction with nickel-plated copper cathodes. They are self-quenching, using ethyl formate whose advantages were discovered and patented by the G.E.C. This quenching agent, compared with the conventional ethyl alcohol, produces tubes with better plateau characteristics, longer life, better temperature coefficient and lower minimum operating temperature. Each tube is individually tested for plateau and background and this data is supplied on a test sheet. The tube characteristics are tabulated overleaf.

OPERATION

Measuring apparatus

It is essential that the recording instrument used with the counter tube be sufficiently sensitive to responded the size of signal obtained at the operating voltage. As in most cases with a short length of shielded cable the signal is only of the order of one volt, a preamplifier is needed when the conventional scaler unit is used. A quenching amplifier, such as the Harwell type 1014A, is preferable to a single-stage amplifier because it improves the plateau characteristics, lengthens the tube life and allows accurate correction to be made for lost counts at high counting rates.

Extreme care should be taken not to reverse the polarity of the voltage applied to the counter tube. Operating the tube at voltages exceeding that stated on the tube will shorten its life considerably.

Temperature effects

The starting voltage increases by 0.25 volt per °C and should be checked under conditions of use. The tube should not be operated below –20°C (as the plateau shortens rapidly) or above 0°C. In accurate measurements, temperature effects should be checked against a standard source.

Hysteresis

At a high counting rate, mica windows may become charged. This increases the starting voltage and decreases the count rate for which allowance can be made.

TD

Photosensitivity

The all-metal types, GM4 and 2B7, are entirely free from this effect. Types EHM2S and 2B2 may exhibit photosensitivity increasing with life. To reduce this effect, specially where the tubes are not operated in a light-tight enclosure or lead castle, the mica windows are coated with a thin layer of graphite. This coating increases the window weight by about 0.25 mg per cm².

Windows

The alloy windows are aluminium (2% magnesium). The 7 mg window is suitable for high energy beta emitter, such as Phosphorous 32 and for medium energy beta emitters such as Iodine 131. The larger diameter window of type 2B7 is intended for measuring specimens of low specific activity. The graph on page 3 shows the relationship between particle energy, percentage of counts and window weights.

The mica windows are graded after cleaving and the grade is shown on the tube to the nearest 0.1 mg. These windows are suitable for low energy beta emitters such as Carbon 14 and Sulphur 35,

GMT 1

Fixing arrangements

The tubes may be clamped by the cathode flange, and the electrical connection made to the clamp or by a clip on the pumping stem. On mica window tubes connection should also be made to the retaining ring covering the edge of the window. The anode connection may be an 8 B.A. nut and bolt, or soldered.

N.B. To avoid damage to the counter, on no account should a soldered connection be made to the pumping stem, nor should the shape of the anode eyelet loop be interfered with unless the wire is supported close to the glass seal with a pair of fine-nose pliers. Care should be taken to avoid damage to the fragile end window which is provided with a protective cover during transport.

Nickel specimen planchets

1.5 and 2.5 cm diameter dished planchets are available to hold specimens 3 mm under the windows of the tubes and give equal sensitivity (*See British Journal of Radiology, Volume 20, No. 233, page 190, 1947*).

1.5 and 2.5 cm diameter flat planchets are also available.

INDIVIDUAL DETAILS	GM4	EHM2S	2B7	2B2	G 150
Average plateau length (minimum 200 volts)	250V	300V	250V	300V	250V
Average plateau slope (maximum 0.1% per volt)	0.05%	0.04%	0.05%	0.04%	0.05%
Operating voltage limits	1250– 1450V	1400– 1600V	1400– 1600V	1400– 1600V	1200– 1400V
Count life (approximate)	6×10^8	6×10^8	4×10^8	4×10^8	2×10^8
Shielded background † (counts per minute)	7–15	5–13	30–46	25–45	1200 (Unshielded)
Temp. Range °C.	–20 to +50	–20 to +50	–20 to +50	–20 to +50	0 to +50
Signal output (volts)*	230 60 + C	1130 40+ C	300 70+ C	200 90+ C	60V (approx.)
Dead time (microseconds)	100	150	220	150	400
Recovery time ,,	250	380	700	750	700
Window thickness (mm)	0.025	0.008	0.025	0.008	–
Window weight (mg/cm²)	7	1.6–2.4	7	1.6–2.4	–
Window material	Alloy	Mica	Alloy	Mica	–
Anode wire diam. (mm)	0.18	0.08	0.13	0.13	0.08
Anode wire length (mm)	26	15	32	20	1350
Anode bead diam. (mm)	2.6 ± 0.2	1.25 ± 0.25	2.6 ± 0.2	1.25 ± 0.25	–
Bead flange clearance (mm)	5.0 ± 0.5	2.25 ± 0.25	8.0 ± 0.5	7.0 ± 0.5	–

* C is the total capacity in pF across the tube. † In 35mm lead castle with ⅛ in. "Perspex" lining.

Filling

Ethyl formate	cm ± 0.25 mm Hg	0.7	0.7	1.0	0.7	1.0
Argon	cm ± 2 mm Hg	6.3	4.3	9.0	9.3	6.5
Helium	cm ± 5 mm Hg	(not used)	60.0	(not used)	55.0	–

PRODUCTION TEST CONDITIONS

The plateau is tested with a series resistance of 4.7 megohms on an electronic scaling unit approved by A.E.R.E. Harwell. (This scaler has an input sensitivity of 0.25 volt and a resolving time of 350 microseconds, with conventional amplifier input stage).

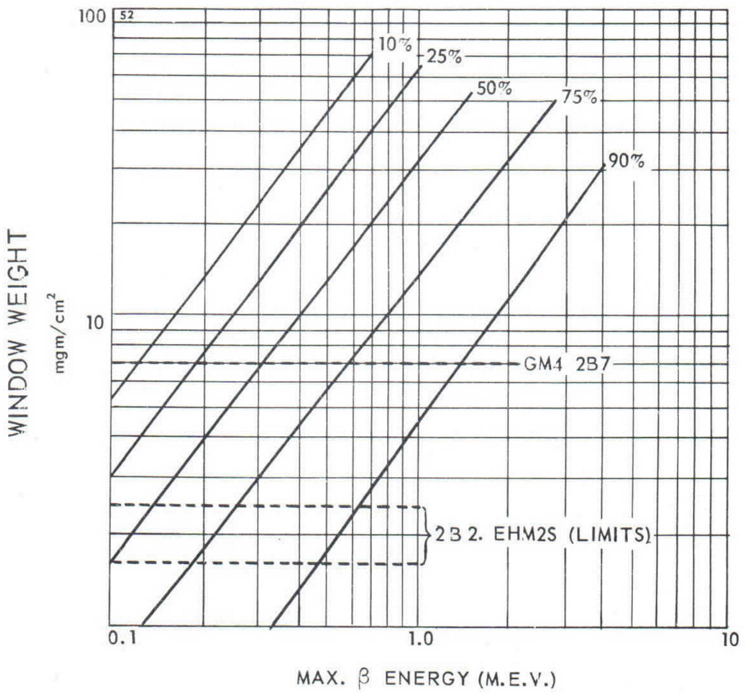
Starting voltage. (Vs). The voltage level at which signals start to operate the counting circuit.

Threshold voltage. The voltage level at which the flat region of the plateau characteristic starts. The threshold voltage is V_S + 40 volts for alloy window types and V_S + 60 for mica window types.

Operating voltage. (V_W). This is the threshold voltage plus 100 volts and is marked on each tube.

Background count. This is measured at the operating voltage for five minutes with the tube in a castle of 35 mm lead and ⅛-in Perspex inner lining.

Life test. This is run at 20,000 counts per minute continuously at the operating voltage and is terminated when the plateau length is reduced to half the minimum (i.e. to 100 volts) or when the plateau slope exceeds the maximum 0.15% per volt.



Percentage transmission of β particles.

Signal output. This is measured at the operating voltage. C is the total capacity in pF across the tube (shielded lead and counting circuit input capacitance).

X-RAY DIFFRACTION TUBE

Type XA1 Designed for high efficiency detection of the Copper K alpha radiation used in X-ray applications.

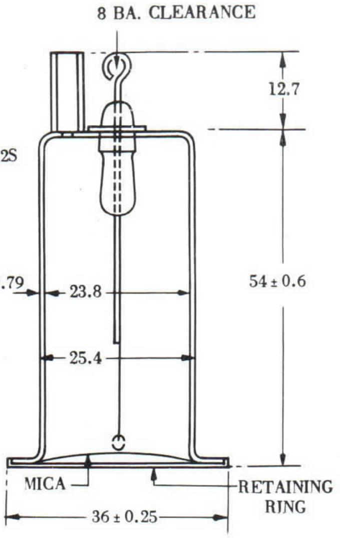
This tube has an iron cathode which should be earthed owing to the conductivity of the soda-lime glass envelope. The beam absorption path is 10 cm parallel to the axis of the tube. The "dead space" behind the window is 2 mm. The mica windows are 0.025 mm thick and weigh 7 mg/cm².

	XA1
Average plateau length (minimum 200 volts)	250V
Average plateau slope (maximum 0.1% per volt)	0.05%
Operating voltage (approx.) ... ... (recommended voltage marked on tube)	1400-1600V
Count life (approximate)	5×10⁸
Shielded background (counts per minute, approx.)†	30
Temperature range °C	−20 to +50 approx.
Signal output (volts)	5
Dead time (microseconds)	250
Recovery time (microseconds)	650
Window thickness (mm)	0.025

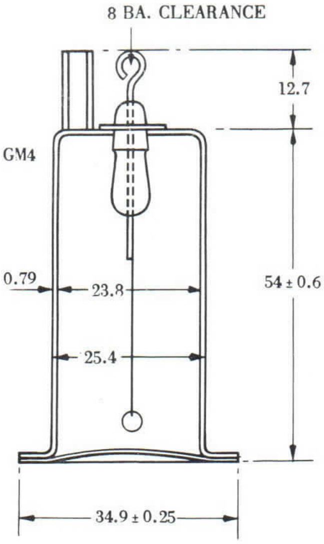
† In 35 mm lead castle with ⅛ in. "Perspex" lining.

Filling	
Ethyl formate cm Hg	1.5
Argon cm Hg	60.0
Krypton cm Hg	–

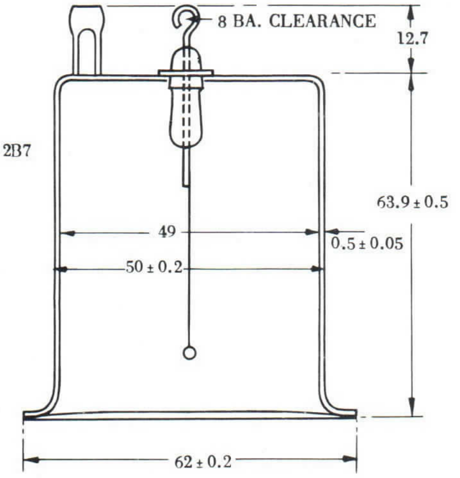
EHM2S



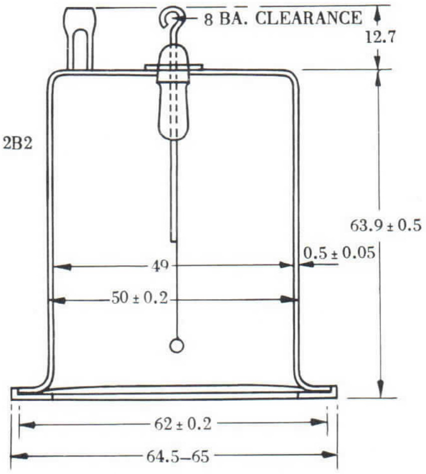
GM4



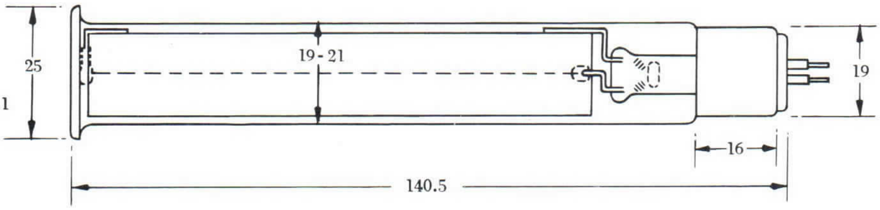
2B7

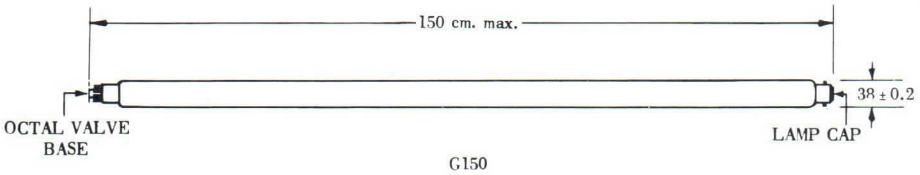


2B2



XA1





G150

All dimensions are in millimetres unless otherwise stated.

TD

EMI Electronics Ltd   Valve Division

HAYES MIDDLESEX ENGLAND (*Controlled by Electric and Musical Industries Ltd*)

Telephone: *Southall 2468*   Cables: *Emidata, London.*   Telex *London 22417*

EMI

EMI ELECTRONICS LTD

Serving Science and Industry

VALVE DIVISION

EMI

GM4LB

GEIGER COUNTER TUBE

The GM4LB is a development from the standard E.M.I. end window Geiger Muller Counter Tube type GM4. It has been specially designed to give a low background count when operated within a guard ring of counters in anti-coincidence when rates as low as 0.4 counts per minute have been recorded. The materials used have been specially selected for freedom from slightly radioactive contaminants such as potassium or solder and a short active length keeps the background due to external radiation to a minimum.

DETAILS

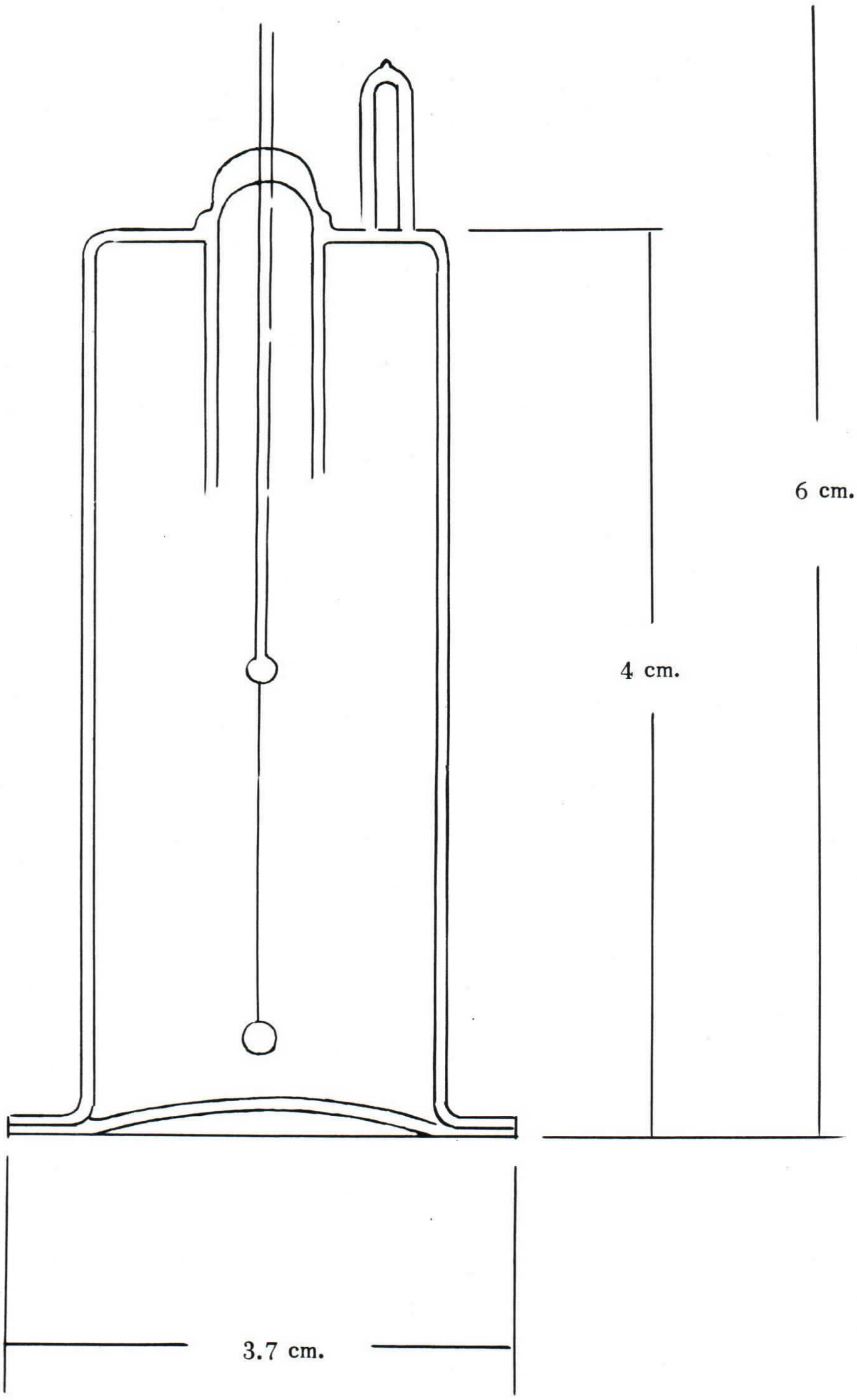
Window of dural	2.5 cm. diam. 7 mgms/cm^2
Active length of counter	15 mm. approx.
Overall length including pump stem and anode connection.	6 cm.
Length of main cylindrical body	4 cm.
Overall window flange diam.	3.7 cm.
Operating voltage	1200 to 1400
Plateau length	150 to 200
Slope	0.1% / volt max.
Gas filling	Argon-ethyl formate.

TD

GMT2

GM4LB

Section through a tube



The Company reserves the right to modify these designs and specifications without notice.

EMI

EMI Electronics Ltd Valve Division

HAYES MIDDLESEX ENGLAND (*Controlled by Electric and Musical Industries Ltd*)

Telephone: *Southall 2468* Cables: *Emidata, London.* Telex *London 22417*

Miscellaneous

EMI

EMI ELECTRONICS LTD
ONE OF THE EMI GROUP OF COMPANIES

VALVE DIVISION

HAYES | MIDDLESEX | ENGLAND

Telephone **HAYES 3888** *Extension* 2165
Telex Number 22417
Telegrams Emidata, Telex, London *Cables* Emidata, London

Our reference 59340/RTM/MJB

Your reference

Dear Sir,

17th December, 1963

THE ELECTRON STICK

A demonstration of the electron stick at the recent conference on microwave valves held under the auspices of the I. E. E. created wide interest in this new EMI device. There will be another opportunity to see a working demonstration in January next at the annual exhibition of the Physical Society to be held in London at the Royal Horticultural Halls.

We feel that, in addition to the obvious value of the electron stick in technical education, many other applications are possible in the industrial fields of design and research. To satisfy the potential demands of such diverse exploitation, special "sticks" are now being offered in addition to the standard 5 mm type. These are:-

Type 9690A	A 3 mm diameter stick with high resistance wall coating, suitable for 0-type interactions where low circuit attenuation is necessary.
Type 9690B	A 3 mm diameter stick with a small diameter (0.020 in) beam. This is more suitable for low voltage transverse wave interaction work.

Availability of these various electron sticks is two to three weeks, and delivery of the accessories listed on the enclosed data sheet can be effected in about six weeks.

We shall be pleased to quote you for your detailed requirements.

Yours faithfully,
EMI ELECTRONICS LTD.

R. T. Mather

R. T. MATHER
Valve Division

EMI
EMI ELECTRONICS LTD
Serving Science and Industry

VALVE DIVISION

THE ELECTRON STICK

Introductory Data

The electron stick is essentially an isolated electron beam, which may be inserted into various external circuits. By this means certain microwave tubes such as the travelling-wave tube, two cavity klystron amplifier, Adler tube and backward-wave amplifier, may be constructed in order to demonstrate the principles of operation in a versatile and inexpensive manner.

The apparatus listed below enables the various experiments to be set up and the more specialised units are available for sale. The signal generator and power units are of a type likely to be found in most laboratories.

The Electron Stick

Length 13 in. approx. Diameter (gun) 1 in. Diameter (tube) 5 mm.

Connections:	Pin 1	Heater	H
	" 2	First Anode	A_1
	" 3	Wall coating	
	" 4	No connection	
	" 5	Second anode	A_2
	" 6	Third anode	A_3
	" 7	Cathode	C
	" 8	Heater	H
		Collector	

Heater Volts

Operation	Vh	6.3V	Ih	0.6A
	A_1 volts		0 to -20	
	A_2 "		100 to 150	
	A_3 "		0 to 100	

Wall coating volts	20 to 300
Collector volts	400
Cathode current	3 mA
Collector current	500 μA

(All voltages referred to cathode)

Focussing field 200 gauss

Circuits

1) Helix for T. W. T. experiment

2) Klystron cavities - two needed for klystron experiment

3) Cuccia coupler) for Adler tube experiment
Quadrupole pump)

Solenoid

Length $16\frac{1}{2}$ in. Diameter 5 in. Weight 15 lb.

Power requirement

100 watts (6A at 17V)

Stick Mounting Cradle

Length 15 in. Diameter $2\frac{3}{4}$ in.

* Signal Source

Approx. 400 - 600 Mc/s (approx. 1 mW into 50Ω)

* Power Supplies

Solenoid	6A at 17V
Stick	giving the specified heater and H. T. requirements

Display Unit

EMI type WM18 or similar (100 mV/cm or better)

Handbook

* All items are available with the exception of those marked *

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