INSTRUMENT CATHODE-RAY TUBE

development sample data

The D13-50../01 is a wide-band oscilloscope tube designed for observation and measurement of high frequency phenomena.
This tube has a rectangular 13 cm diagonal flat face with aluminized screen and internal graticule, post-deflection accelerator with mesh, vertical deflection by means of a symmetrical helix system, scan magnification in the vertical direction by means of an electrostatic quadrupole lens and correction coils for trace alignment, vertical shift of the display area and correction of the orthogonality of traces.

QUICK REFERENCE DATA			
Final accelerator voltage	$V_{g12(\ell)}$	15	kV
Display area	100 ×	60	mm^2
Deflection factor, horizontal	M_x	15	V/cm
vertical	M_y	2	V/cm
Bandwidth of the vertical deflection system	B	800	MHz

SCREEN

	colour	persistence
D13-50GH/01	green	medium short

Useful screen dimensions min. 100 × 60 mm^2

Useful scan at $V_{g12(\ell)}/V_{g2} = 6$

horizontal	min.	100	mm
vertical	min.	60	mm

By means of adjusting the current in the correction coils, full coverage of the internal graticule by the scanned area can be obtained for any tube.

These data, based on the specifications and measured performance of development samples, afford a preliminary indication of the characteristics to be expected of the described product. Distribution of development samples implies no guarantee as to the subsequent availability of the product

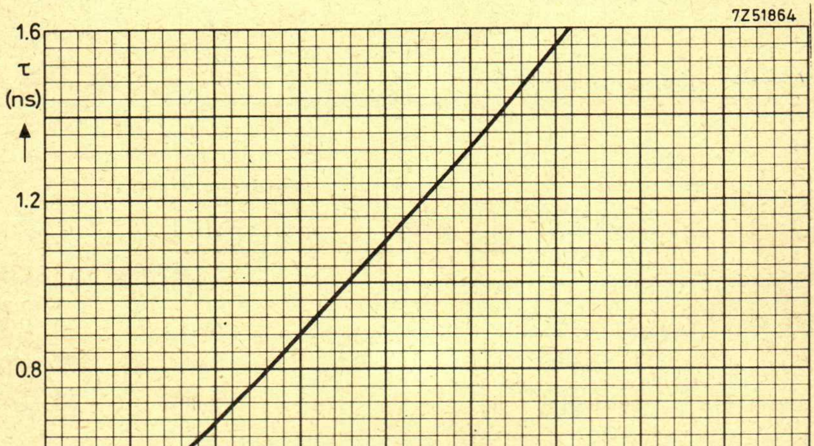
DESCRIPTION

General

The D13-50../01 has been primarily designed for wide-band high-frequency applications. It combines high brightness, high deflection sensitivity and a large band-width of the vertical deflection system.

In order to obtain the high sensitivity, the post-deflection acceleration system embodies a mesh. The sensitivity in the vertical direction has been further increased by means of an electrostatic quadrupole lens that has been inserted between the vertical deflection system and the horizontal deflection plates. The large band-width has been obtained by using, for the vertical deflection, a delay-line system instead of deflection plates. With the typical operating conditions, 2500 V first accelerator voltage and 15000 V final accelerator voltage, the vertical and the horizontal deflection factors are about 2 V/cm and 15 V/cm respectively, with a 10 x 6 cm^2 display area.

The bulb has a rectangular face and the screen is aluminized. To eliminate parallax errors, an internal graticule is incorporated. Correction coils have been provided to permit image rotation, correction of the orthogonality of traces and the adjustment of the vertical useful scan with respect to the graticule.



Rise time of the display τ as a function of the rise time of the input signal τ_2

fig. 1

The vertical deflection system

For the vertical deflection, a delay-line system is used so that transit-time effects are practically eliminated. The system consists of two flattened helices to which a symmetrical deflection signal should be applied. Under these conditions, the characteristic impedance of each helix is 150 Ω. The input and output terminals are brought out on opposite sides of the neck on the same plane. The input terminals are connected to the beginning of the helices by means of a matched, internal two-wire transmission line. The output of the deflection system should be properly terminated in order to avoid signal reflections.

With the typical operating conditions, the band-width of the deflection system, i.e. the frequency at which the sensitivity is 3 dB below its value at D.C., is about 800 MHz. Even above this frequency, the response decreases only gradually so that, for narrow-band applications, the tube can be used with reduced vertical sensitivity up to about 2000 MHz.

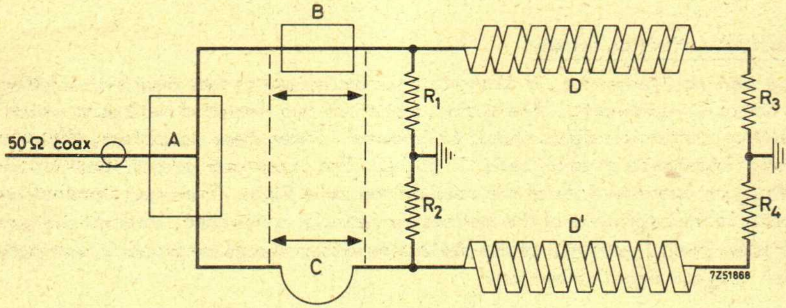
The rise-time τ_1, i.e. the time interval during which the display of an ideal step-function signal applied to the input goes from 10% to 90% of its final value, is about 0.45 ns. If the input signal has the rise-time τ_2, the rise-time τ of the display is approximately given by

$$\tau = \sqrt{\tau_1{}^2 + \tau_2{}^2}$$

In fig. 1, τ has been plotted as a function of τ_2, with $\tau_1 = 0.45$ ns. If, for example, the tube is used in combination with an amplifier and the rise-time of the display is to be 1.4 ns (corresponding with 250 MHz band-width), the rise-time of the amplifier should be 1.33 ns. It can be seen that in this region the rise-time of the display is almost equal to the amplifier rise-time, without a significant contribution of the cathode-ray tube.

If the tube is to be used without an amplifier in order to make use of its full band-width capabilities, care should be taken to ensure good symmetry of the input signal.

Fig. 2 shows how the tube can be connected to a 50 Ω coaxial input. A matched power divider is used which delivers two identical output signals. One of these is inverted by means of a pulse inverter. An additional length of 50 Ω cable should be inserted into the path of the non-inverted signal having the same delay time as the pulse inverter so that the two signals arrive at the input of the deflection system at the same time. The 75 Ω shunt resistors serve to obtain a correct termination of the 50 Ω lines. Since each branch of the power divider has 6 dB attenuation, the sensitivity, measured at the 50 Ω input, is also 2 V/cm.



Connection to an asymetrical 50 Ω input

A: Power divider — R_1, R_2 : Resistors 75 Ω

B: Inverter — R_3, R_4 : Resistors 150 Ω

C: Cable — D, D' : Deflection system

Note: Delay of inverter B and cable C are equal fig. 2

Scan magnifier and focusing system

As already mentioned, an electrostatic quadrupole lens, i.e. an electron lens which has two mutually perpendicular planes of symmetry, divergent in one plane and convergent in the other, is used for the magnification of the vertical deflection. This lens is inserted between the vertical deflection system and the horizontal deflection plates, with its plane of divergence in the direction of the vertical deflection. Therefore, it magnifies the vertical deflection without affecting the horizontal deflection.

Because of the astigmatic properties of this quadrupole lens, a conventional, rotationally symmetrical focusing lens cannot be used. Instead of this, two more electrostatic quadrupole lenses are incorporated so that focusing is accomplished by means of three quadrupole lenses, with alternating orientation of their planes of convergence and divergence. The focusing action is schematically shown in fig. 3.
The strength of the scan-magnifier lens is controlled by applying to the electrode g_8 a negative voltage with respect to g_2. Within a certain range of this voltage, corresponding to a scan-magnification factor Msc, i.e. the ratio of the deviations on the screen with and without scan magnification respectively, between 1.8 and 2 the combined effect of the three lenses will yield an approximately circular spot at moderate beam currents. (At high beam currents, when space-charge repulsion causes an increase of spot size, the width of the vertical lines will be smaller than that of the horizontal lines).

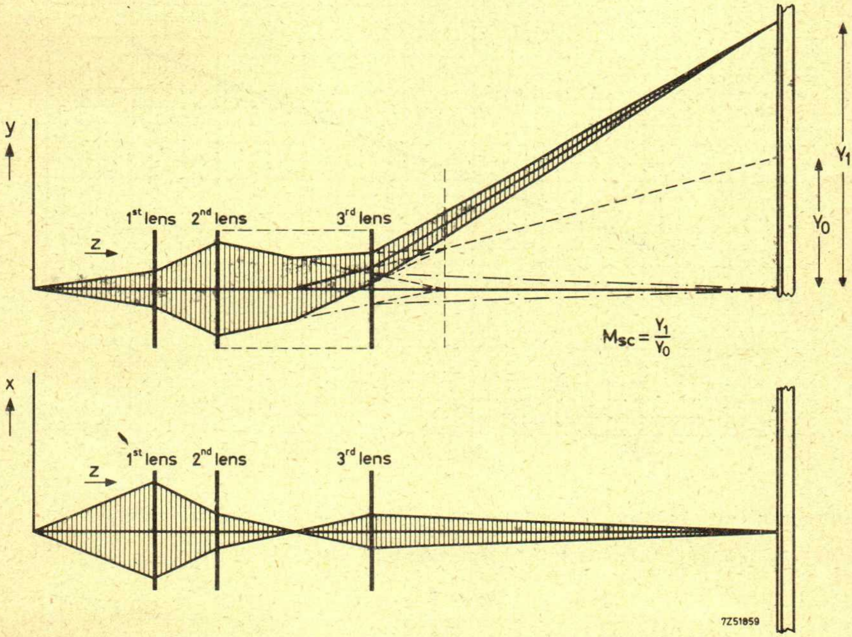
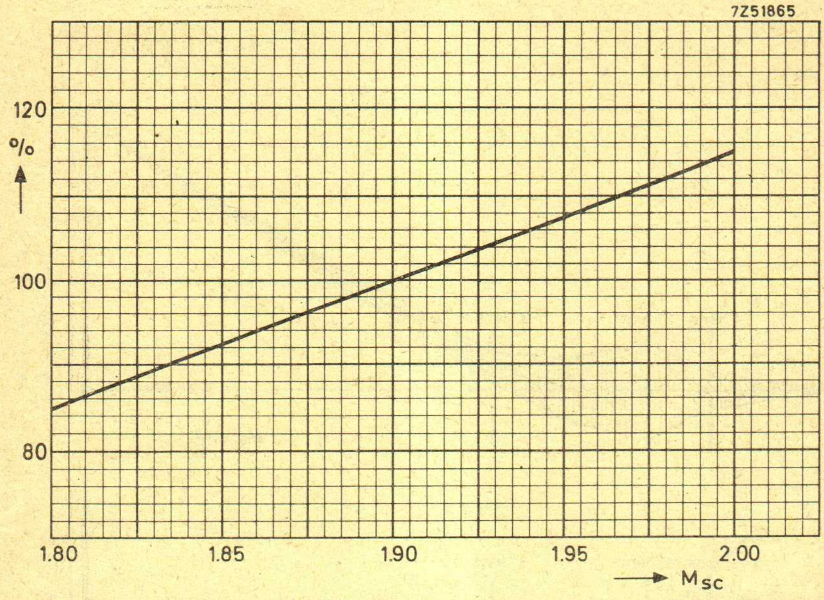


fig. 3

In this range, line-width at a fixed value of screen current, and screen current at a fixed value of grid nr. 1 voltage, are increasing functions of the scan-magnification factor. Figs. 4 and 5 show the average relative change with respect to the values at Msc = 1.9 which, generally, is the most suitable compromise.

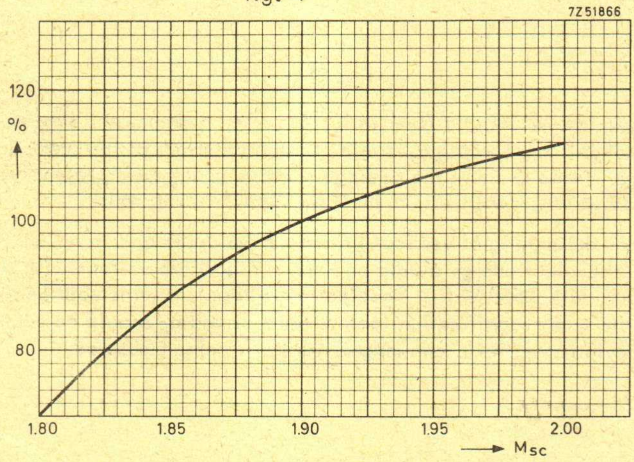
For minimum defocusing of vertical lines near the upper and lower edge of the display area, the electrode g_7 should be kept at a positive voltage with respect to g_2 (about 200 V with 2500 V first accelerator voltage). As this voltage also has some effect on the scan-magnification factor, both g_7 and g_8 should be connected to g_2 when the deviation without scan magnification is being measured.



Line-width as a function of the scan-magnification factor (approximately)

Line-width at M_{sc} = 1.9 is 100 %, I_{ℓ} = const.

fig. 4



Screen current as a function of the scan-magnification factor (approximately)

Screen current at M_{sc} = 1.9 is 100 %, V_{g1} = const.

fig. 5

For the adjustment of the scan-magnification factor the following procedure is recommended:

a. Set V_{g7} and V_{g8} to 0 with respect to g_2.

b. Displaya time-base line and adjust V_{g5} so that the line appears sharply focused.

c. Apply a square wave signal to the vertical deflection system (the vertical parts of the trace will be out of focus but this is immaterial) and adjust the amplitude so that the height of the display has a convenient value, e.g. 30 mm.

d. Set V_{g7} and V_{g8} to the appropriate values and readjust V_{g5} so that the horizontal parts of the trace are again in focus.

e. Check the height of the display (e.g. for $M_{sc} = 1.9$ this height should now be 57 mm).

f. If necessary, readjust V_{g8} until the desired value of M_{sc} has been obtained.

Focusing is controlled by means of the electrode voltages V_{g3} and V_{g5}. Having two focus controls is, in fact, not an extra complication, as a separate astigmatism control is not required. The electrodes g_4 and g_6 can be used to centre the beam with respect to the vertical and horizontal deflection systems.

The voltages of the focusing and correction electrodes can be adjusted as follows:

a. Display a square-wave signal on the screen so that both horizontal and vertical traces are visible.

b. Adjust V_{g5} so that the horizontal parts of the display are in focus.
The vertical parts will, in general, be out of focus.

c.. Adjust V_{g3} so that the vertical traces are brought into focus.
Now the horizontal parts of the display will be out of focus again.

d. Repeat b) and c) successively until both vertical and horizontal traces are simultaneously in focus.

e. Adjust V_{g6} for equal brightness at the left-hand and right-hand edges of the display area. If necessary, readjust the focus be means of V_{g5}.

f. Adjust V_{g4} so that the position of a horizontal trace not deflected in the vertical direction is at the centre of the vertical useful scan. If necessary, readjust the focus by means of V_{g3}.
If the graticule is not fully covered by the scanned area the image should be shifted by adjusting the correction coil current (see page 16) before the adjustment of V_{g4} is made.

The procedure for the adjustment of the scan-magnification factor and for focusing, as described above, seems to be rather complicated.
However, in practice it will be suffucient to adjust V_{g8} to its nominal value without determining the scan-magnification factor for each individual tube. As to focusing, the user can, with some experience, achieve the best setting with very few adjustments.

Post-deflection acceleration

The use of a p.d.a. shield (mesh) ensures a high deflection sensitivity. A geometry control electrode, g_{10}, serves for the correction of pin cushion or barrel distortion of the pattern. In order to suppress background illumination due to secondary electrons originating from the p.d.a. shield g_{11}, this shield should be kept 12 V negative with respect to g_{10} whereas the voltage of the interplate shield, g_9 should be equal to the mean x-plate potential.

HEATING: Indirect by A.C. or D.C. : parallel supply

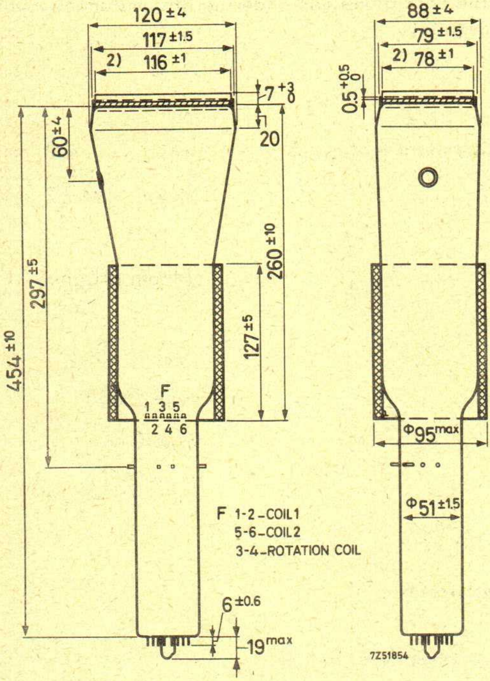
Heater voltage	V_f	6.3	V
Heater current	I_f	300	mA

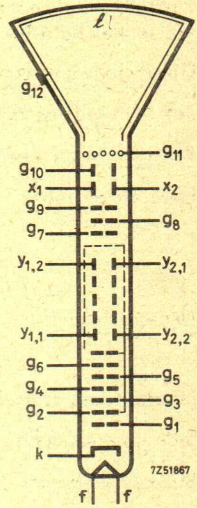
CAPACITANCES

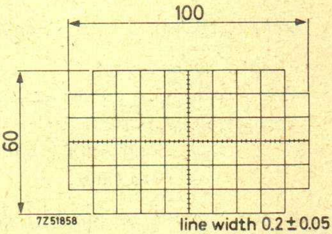
x_1 to all other elements except x_2	$C_{x1(x2)}$	4.5	pF
x_2 to all other elements except x_1	$C_{x2(x1)}$	4.5	pF
x_1 to x_2	C_{x1x2}	2.7	pF
Control grid to all other elements	C_{g1}	6	pF
Cathode to all other elements	C_k	5	pF

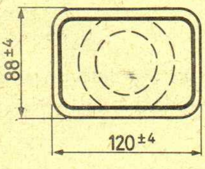
1) Clear area for light conductor
2) These dimensions apply to the illumination plate which will always be within the limits 117 $\pm$1.5 x 79 $\pm$1.5 mm of the tube face.

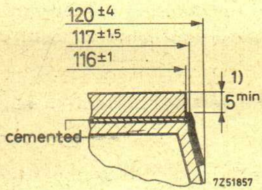
MECHANICAL DATA

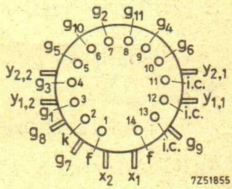












Notes: see page 8

MECHANICAL DATA (continued)

Mounting position: any

The tube should not be supported by the base alone and under no circumstances should the socket be allowed to support the tube.

Dimensions and connections

See also outline drawing

Overall length (socket and front glass plate inclusive)	max.	493 mm
Face dimensions	max.	124x92 mm^2

Base	14-pin all glass
Accessories	
Socket	type 55566
Final accelerator contact connector	type 55563
Side contact connector	type 55561
Mu-metal screen	type 55582

FOCUSING electrostatic [1]

DEFLECTION double electrostatic

x plates symmetrical
The y deflection system consists of a symmetrical delay line system.

Characteristic impedance	2x150 Ω
Bandwidth (-3dB)	800 MHz [2]
Rise time	0.45 ns [3]

If use is made of the full deflection capabilities of the tube the deflection plates will intercept part of the electron beam: hence a low impedance deflection plate drive is desirable.

Angle between x and y traces 90°. [4] (see page 14 "Correction coils")

[1] Because of the applications of a quadrupole lens for the magnification of the vertical deflection, two more quadrupole lenses are used for focusing. Therefore, controls for two voltages have to be provided but a separate astigmatism control voltage is not required.

[2] The band-width is defined as the frequency at which the vertical deflection sensitivity, is 3 dB lower than at D.C.

[3] The rise-time is defined as the time interval between 10% and 90% of the final value of deflection when an ideal step-function signal is applied to the vertical

deflection system. If the actual signal has an appreciable rise-time, τ_2, the rise-time of the tube can be determined from

$$\tau_1 = \sqrt{\tau^2 + \tau_2^2}$$

where τ is the rise-time observed on the display.
This should be measured after the angle between the x-traces and y-traces has been corrected by means of the correction coils, otherwise two measurements have to be taken (using either a different polarity of the vertical deflection signal or different direction of the time-base sweep) and the true value of τ has to be calculated as the arithmetic mean of the two results.

4) Deviations from the orthogonality of traces can be eliminated by means of correction coils.

LINE WIDTH

Measured with the shrinking raster method in the centre of the screen under typical operating conditions, adjusted for optimum spot size at a beam current I_ℓ = 10μA and a screen magnification factor M_{sc} = 1.9. See also 3), page 13.

Line width	l.w.	approx. 0.35	mm	

TYPICAL OPERATING CONDITIONS

Final accelerator voltage	$V_{g12(\ell)}$	15000	V	
Post deflection shield voltage (with respect to g_{10})	$V_{g11-g10}$	-9 to -15	V	
Geometry control electrode voltage	V_{g10}	2500 ± 100	V	1)
Interplate shield voltage	V_{g9}	2500	V	2)
Scan magnifier electrode voltage (with respect to g_2)	V_{g8-g2}	-250 to -375	V	3)
Correction electrode voltage (with respect to g_2)	V_{g7-g2}	+200	V	4)
Horizontal beam centering electrode voltage	V_{g6}	2500 ± 50	V	6)
Vertical beam centering electrode voltage	V_{g4}	2500 ± 50	V	5)
Focusing electrode voltages (with respect to g_2)	V_{g5-g2} V_{g3-g2}	-400 to -600 -600 to -800	V V	
First accelerator voltage	V_{g2}	2500	V	
Control grid voltage for visual extinction of a focused spot	V_{g1}	-50 to -150	V	
Deflection factor, horizontal vertical	Mx My	approx. 15 approx. 2	V/cm V/cm	7)
Deviation of linearity of deflection		2	%	8)

Notes see page 13

Geometry distortion				see 9)
Useful scan, horizontal			100	mm
vertical			60	mm

LIMITING VALUES (Absolute max. rating system)

Final accelerator voltage	$V_{g12(\ell)}$	max.	20000	V
		min.	9000	V
Post deflection shield voltage	V_{g11}	max.	3100	V
Geometry control electrode voltage	V_{g10}	max.	3100	V
Interplate shield voltage	V_{g9}	max.	3100	V
Scan-magnifier electrode voltage	V_{g8}	max.	3100	V
Correction electrode voltage	V_{g7}	max.	3200	V
Focusing electrode voltages	V_{g5}	max.	3000	V
	$-V_{g5-g2}$	max.	1000	V
	V_{g3}	max.	3000	V
	$-V_{g3-g2}$	max.	1000	V
Beam centering electrode voltages	V_{g6}	max.	3100	V
	V_{g4}	max.	3100	V
First accelerator voltage	V_{g2}	max.	3000	V
		min.	2000	V
Control grid voltage, negative	$-V_{g1}$	max.	200	V
positive	V_{g1}	max.	0	V
Cathode to heater voltage				
cathode positive	$V_{+k\,f}$	max.	200	V
cathode negative	$V_{-k\,f}$	max.	125	V
Voltage between first accelerator and any deflection electrode	$V_{g2\,x}$	max.	500	V
	$V_{g2\,y}$	max.	500	V
Screen dissipation	W_{ℓ}	max.	3	mW/cm^2
Ratio $V_{g12(\ell)} / V_{g2}$	$V_{g12(\ell)}/V_{g2}$	max.	10	
Average cathode current	I_k	max.	300	μA

Notes to pages 11 and 12

1) This voltage should be adjusted for optimum pattern geometry.

2) This voltage should be equal to the mean x-plate potential.

3) The range indicated corresponds to a scan magnification factor M_{sc}, i.e. the ratio by which the vertical deviation on the screen is increased, in the approximate range $1.8 < M_{sc} < 2.0$, and the tube should not be operated outside this range. Within this range, line-width and screen current at a fixed value of the control-grid voltage are increasing functions of M_{sc}. The best compromise between brightness and line width is usually found at $M_{sc} \approx 1.9$ which corresponds to $V_{g8-g2} \approx$ 310 V.

4) For minimum defocusing of vertical lines near the upper and lower edges of the scanned area this voltage should be approximately adjusted to the value indicated. Since the value of V_{g7-g2} has some effect on the scan-magnification factor both V_{g7} and V_{g8} should be connected to g_2 when the deviation without scan magnification is to be measured.

5) By adjusting this voltage a spot not deflected in the vertical direction may be centered with respect to the vertical useful scan.

6) This voltage should be adjusted for equal brightness in the x-direction with respect to the electrical centre of the tube.

7) For a scan-magnification factor M_{sc} = 1.9. In the above mentioned range of V_{g8-g2} the vertical deflection factor will vary approximately ± 5 %.

8) The sensitivity at a deflection of less than 75 % of the useful scan will not differ from the sensitivity at a deflection of 25 % of the useful scan by more than the indicated value.

9) A rectangle of 98 by 58.2 mm^2 is concentrically aligned with the internal graticule of the tube. The edges of a raster will fall between this rectangle and the boundary lines of the internal graticule with correction potentials applied.

CORRECTION COILS

The tube is provided with a coil unit consisting of:

1. a pair of coils (nrs. 1 and 2), with approx. 220 Ω D.C. resistance per coil, for
   a) correction of the orthogonality of the x- and y-traces so that the angle between these traces at the centre of the screen can be made exactly 90°.
   b) vertical shift of the scanned area.
2. a single coil (nr. 3) with approx. 550 Ω D.C. resistance, for image rotation (alignment of the x-trace with the x-lines of the graticule).

Orthogonality and shift:

The change in the angle between the traces and the shift of the scanned area will be proportional to the algebraic sum and the algebraic difference of the currents in the coils nrs. 1 and 2.
Under typical operating conditions and with the coil unit closely surrounded by a mu-metal shield, the currents required are max. 5 mA per degree of angle correction and max. 2 mA per millimeter shift. The supply circuit for these coils should be so designed that in each coil a maximum current of 20 mA, with either polarity, can be produced.

If a wider mu-metal shield is used the above-mentioned values have to be multiplied by a factor K ($1 < K < 2$) the value of which depends on the dimensions of the shield and approaches 2 for the case no shield is present.

Image rotation:

Under typical operating conditions, a current of max. 45 mA will be required for the alignment.

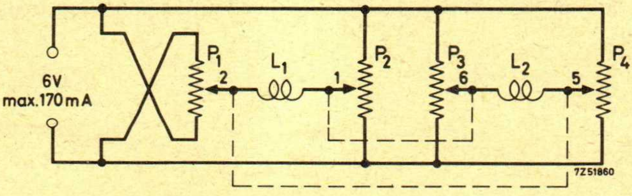


fig. 1

P_1, P_2 potentiometers 220Ω, 1 W: ganged

P_3, P_4 potentiometers 220 Ω, 1 W: ganged

With the above circuit almost independent control for shift and angle correction is achieved. This facilitates the correct adjustment to a great extent.
The dissipation in the potentiometers can be reduced considerably if the requirement of independent controls is dropped (see fig. 2)

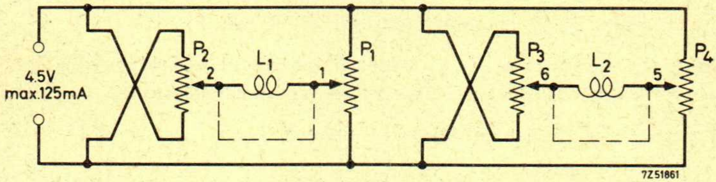
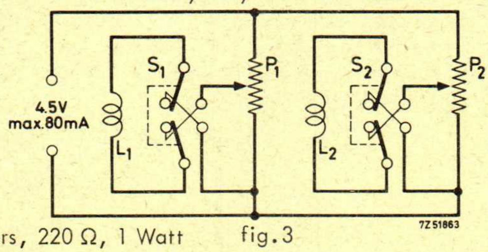


fig. 2

P_1, P_2 potentiometers 220 Ω, 1 Watt: ganged

P_3, P_4 potentiometers 220 Ω, 1 Watt: ganged

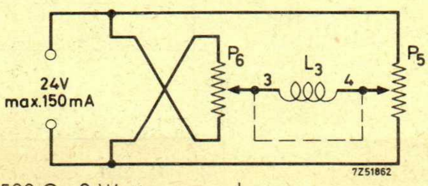
A further reduction of the dissipation can be obtained by providing a commutator for each coil (see circuit fig. 3).
The procedure of adjustment will then become more complicated but it should be kept in mind that a readjustment is necessary only when the tube has to be replaced.



P_1, P_2 potentiometers, 220 Ω, 1 Watt fig.3

S_1, S_2 commutators

A suitable circuit forthe image rotating coil is given in fig. 4.



P_5, P_6 potentiometers 500 Ω, 3 Watt: ganged fig. 4

The following procedure of adjustment is recommended

a. Align the x trace with the graticule by means of the image rotating coil.

b. With the tube fully scanned in the vertical direction, the image has to be shifted so that the graticule is fully covered. With the circuit according to fig. 1 this is done by means of the ganged potentiometers P_1 and P_4.

c. Adjustment of orthogonality by means of the ganged potentiometers P_2 and P_3. A slight readjustment of P_1 and P_4 may be necessary afterwards.

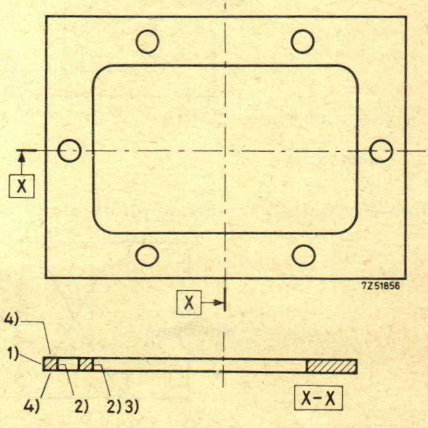
d. Readjustment of the image rotation if necessary.

With a circuit according to fig. 2 or 3 these corrections have to be performed by means of successive adjustments of the currents in the coils.

The most convenient deflection signal is a square wave form permitting an easy and fairly accurate visual check of orthogonality.

ILLUMINATION OF THE GRATICULE

To illuminate the internal graticule a light conductor (e.g. of perspex) should be used. In order to achieve the most efficient light conductance, the holes for the lamps and the edge adjacent to the tube should be polished, and the distance between the perspex plate and the tube should be as small as possible. It is advisable to apply reflective material to the outer circumference and, if possible, also to the upper and lower faces of the light conductor. The thickness of the conductor should not exceed 3 mm, and its position relative to the frontplate of the tube should be adjusted for optimum illumination of the graticule lines.



1) Reflective material.

2) Polished.

3) Close and constant distance to front plate of tube.
It is necessary that the light conductor and the front plate of the tube are in plane.

4) If possible reflective material.