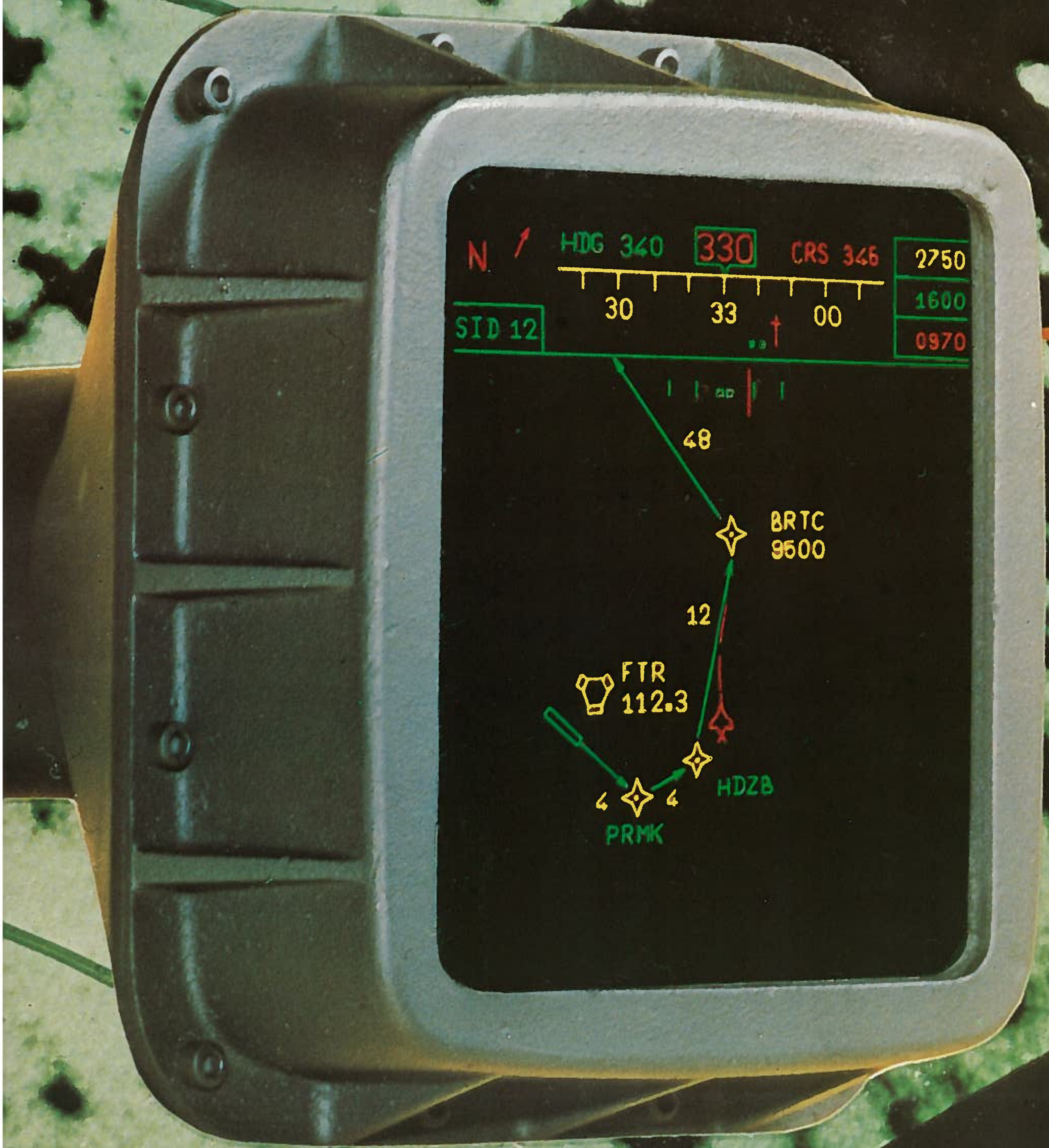
ELECTRON TUBE DIVISION

NTV 6248

PENETRATION CATHODE RAY TUBES



THOMSON-CSF
COMPONENTS

NTV 6248A

November 1982

PENETRATION CATHODE-RAY TUBES

CONTENTS

The advantages of penetration CRTs

Although color is an extremely effective tool for displaying visual information, until recently most CRTs designed for radar and graphics applications showed only monochorme pictures — somewhat surprising, since color effectively increases the legibility of a display, while reducing the time needed to read it.

The penetration CRT meets the requirements for a good information-display tube. Compared to the shadow-mask tube, the penetration CRT offers increased luminance and resolution. In addition, the penetration CRT can operate in high vibration/ shock environments — something the shadow-mask tube has not been designed for.

	Penetration tube	Shadow-mask tube
Basic phosphors	green and red or red and white or special phosphors	green, blue, and red
Type of screen	layers	dots
Number of guns	one	three
Number of colors displayed when used for a display console	a minimum of 4, for green and red phosphor tubes	many
Full screen luminance	200 cd/m²	100 cd/m²
Resolution (TV lines per raster height)	1000 to 1500	550
Type of scanning	TV raster or random scanning	TV raster
Necessary auxilliaries	high-voltage switching and associated deflection correction, standard deflection yokes	convergence coils and associated circuitry, special deflection yokes
Sensitivity to earth and stray magnetic fields	very small displacements without any loss of purity	high
Moiré or interference patterns	none	high
Sensitivity to shock and vibrations	very small	high

Table I — Comparison between penetration-type and shadow-mask CRTs

What are penetration CRTs ?

PRINCIPLE OF OPERATION

A penetration CRT is essentially the same as a normal CRT, except that the standard phosphor screen has been replaced by what is known as a **penetration phosphor screen** (Figure 1). This consists schematically of two different phosphors separated by a transparent layer of dielectric material that is unaffected by electron bombardment.

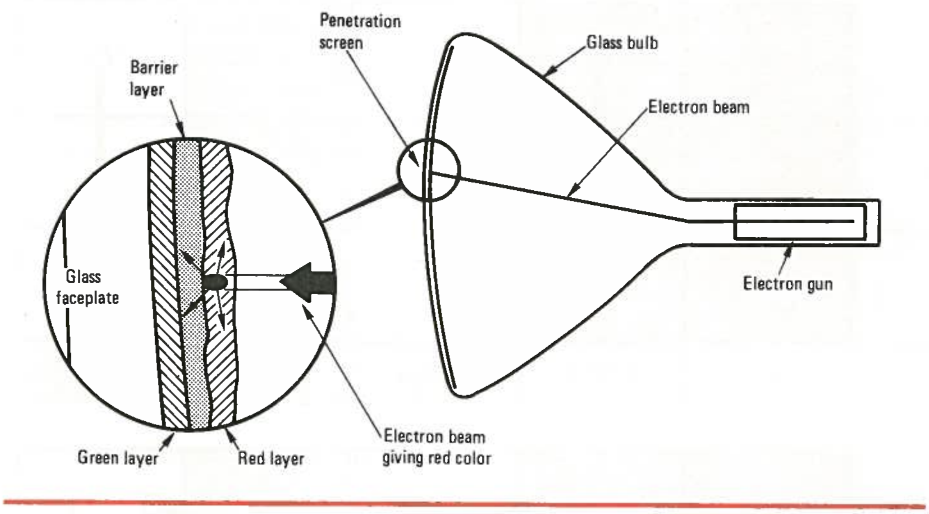


Figure 1 — A multilayer screen is the key to operation of the color-penetration CRT. Low-voltage electrons excite only one phosphor layer ; a high-voltage beam penetrates the dielectric barrier layer and excites the second phosphor

The phosphors have either different colorimetric or temporal characteristics, or both. At low electron-accelerating voltages, **only the first phosphor is excited by the electron beam, and it fluoresces with a well-defined color, spectral response, and persistence** Both phosphors fluoresce at high voltages, but as most of the beam energy is absorbed by the second one, it is this phosphor that defines the predominant color and temporal response. At mid-range voltages, the resulting fluorescence is a mixture of the fluorescences of the two phosphors. In this way, changes in color and persistence, or both, can be obtained by simply altering the CRT accelerating voltage.

CLASSIFICATION

The specific changes obtained in color, persistence, or both together, will depend upon the phosphors used. If only the colorimetric characteristics are different, the resulting tube is a **multicolor penetration CRT** (Figure 2a) ; if only the temporal characteristics are different, the tube is a **variable-persistence-penetration CRT** (Figure 2b), and if both are different, the tube is a **multicolor, multipersistence-penetration CRT** (Figures 2c and 2d).

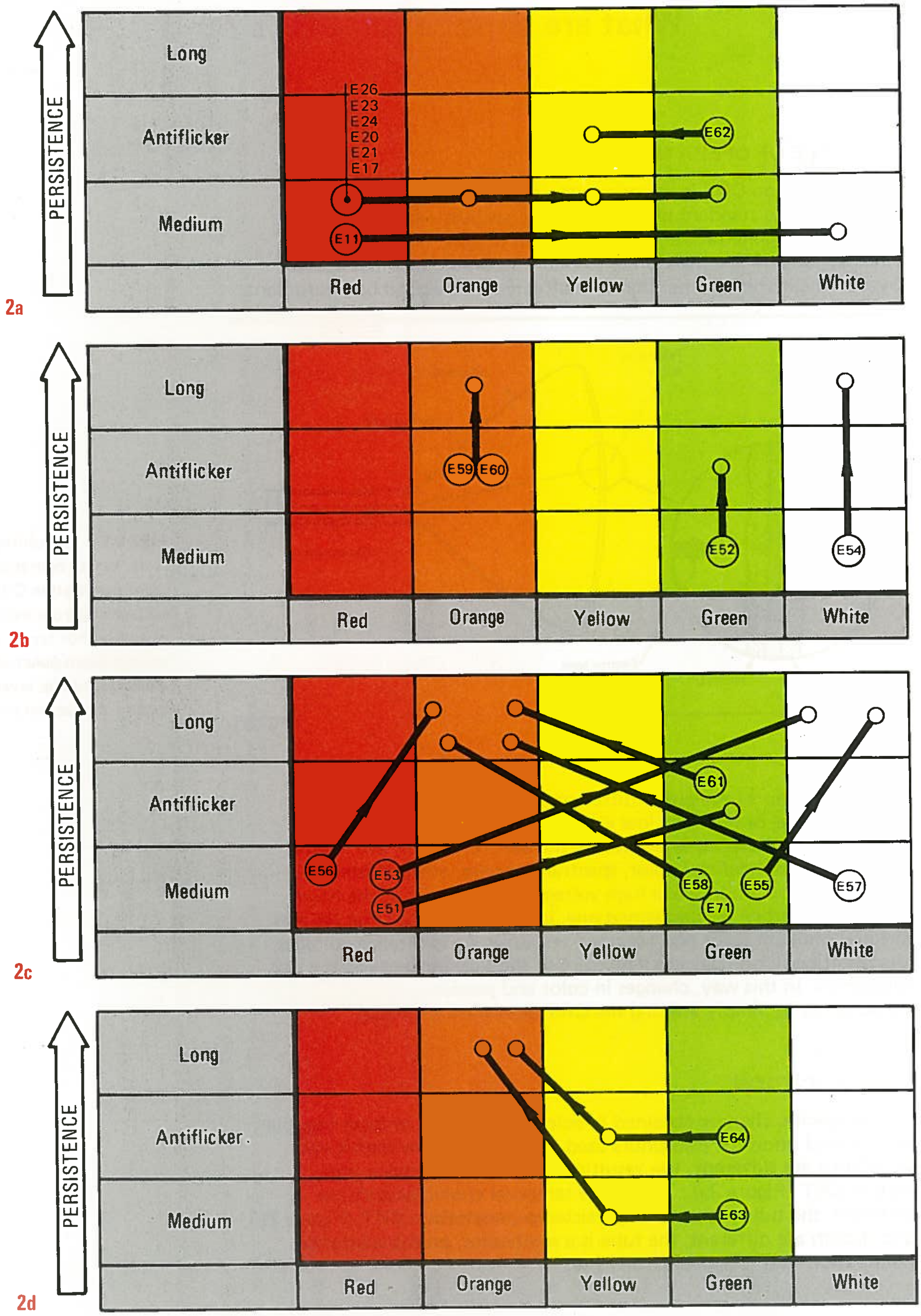


Figure 2 — Characteristics of the various penetration-phosphor screens

Remark : On these figures, the arrows indicate variation in color or persistence when the accelerating voltage is increased

FEATURES

VIBRATION-RESISTANT

Penetration CRTs use standard electron guns. Because of this, these tubes perform extremely well in high-vibration environments : spot position is stable, and the displayed color remains pure. Another result of their simple mechanical structure is that the deflection angle is not limited by a color-separation mask.

EXCELLENT SPATIAL RESOLUTION

Spatial resolution is extremely good ; the phosphor alone would allow 12 lp/mm. In actual practice, resolutions of 3 to 10 lp/mm at 50 % modulation can be obtained under normal lighting conditions, a performance that is much better than that of shadow mask or similar tubes.

In this type of application, which requires extremely high contrast values, contrast enhancement can be achieved by means of directive filters or honeycomb structures, which restrict the illumination of the screen to a narrow solid angle, normally shadowed by the observer. To increase the filter efficiency, stray reflections must be eliminated. Antireflection coatings very effectively solve this problem. Recently, a slight etching of the display surface has been introduced, which diffuses the reflected images. In concert with an antireflection coating, this combination results in the best antiglare conditions attainable.

APPLICATIONS OF MULTIFUNCTION PENETRATION SCREENS

THE ADVANTAGES OF COLOR PLUS VARIABLE PERSISTENCE

In display consoles (alphanumeric or graphic), color serves as an "attention getter" ; it improves the legibility and quality of many displays, reduces search time, and gives better recognition accuracy.

In radar consoles, multifunction CRTs allow simultaneously displaying, without confusion, synthetic video information (figures, positions, symbols) in one or several colors with short persistence, and PPI-scanned information, in different colors. This makes the CRT suitable for air-traffic control, especially under heavy traffic conditions.

In airborne applications, mainly for Electronic Attitude Director Indicators (EADI), color CRTs provide adequate luminance and contrast for a head-down display (HDD) of computer-generated information corresponding to different phases of the flight.

How are penetration CRTs used ?

SEQUENTIAL PRESENTATION OF INFORMATION

CHOICE OF ADDRESSING

The penetration tube, using only one electron gun (see Figure 1), displays one color per level of high voltage. Therefore, it cannot display several colors simultaneously. Because of this, multi-colored images are obtained by writing the different colors sequentially at a sufficiently high frequency, the eye's retinal persistence giving the illusion of continuity as it does with a standard CRT.

Like monochrome tubes, multifunction penetration CRTs can be addressed in many ways, such as random access, TV raster and radar PPI. The technique used is determined by the phosphor combination, and the application envisaged. Several ways of addressing can be used sequentially to give the impression that different types of information are being displayed simultaneously.

Stroke Writing

THE PREFERABLE SCANNING MODE

This scanning mode makes the best use of penetration CRTs since dead times are minimized.

The data must be displayed at a refresh rate that is compatible with the phosphor's persistence characteristics (e.g., 50 Hz for the E21). The dead time, during which time the screen cannot be used (i.e., the switching time), depends on the number of colors to be displayed within the refresh period, and the rise time of the voltage switch. The dwell time for each color within this refresh period depends on the best compromise between the luminance and the data load, since the higher the load and the faster the scanning speed, the lower the luminance.

TV Raster

A TV SCAN MAY BE USEFUL

The high scanning speed involved in standard TV leads to low luminance, and therefore, makes poor use of this kind of device. On the other hand, switching rise times being always longer than 20 μs, color cannot be changed from one pixel to the next one, and TV scans can only be used for the superposition and succession of monochrome images.

In some cases, with raster parameters well matched to the situation, a TV scan may, however, be useful.

PPI Scan

This kind of scan is generally employed in the high-voltage mode for multipersistence screens such as the E58, E63 and E71.

COMPENSATING THE SCANNING AMPLITUDE

The scanning amplitude depends on the deflection angle, θ, which is given by the relationship :

$$\sin\theta = ni\frac{l}{d}\sqrt{\frac{e}{2m}\frac{1}{V_b}}$$

where :

$\frac{e}{m}$ is the ratio of the charge to the mass of an electron,
d is the inside diameter of the deflection yoke,
l is the length of the deflection field,
n is the number of turns in the yoke, and
i is the current in the yoke, and
V_b is the electron-beam accelerating voltage.

As the scanning amplitude depends on V_b, some form of compensation is required to cater for the different operating mode voltages.

This is done by altering the gain of the deflection amplifiers. For small deflection angles, θ is inversely proportional to $\sqrt{V_b}$, so for two different values of V_b, the deflection amplitude A_1 and A_2 are related as follows :

$$\frac{A_1}{A_2} = \frac{i_1}{i_2}\sqrt{\frac{V_{b2}}{V_{b1}}}$$

So, to keep the same system gain for two operating voltages, the relationship :

$$i_1\sqrt{V_{b2}} = i_2\sqrt{V_{b1}}$$

must be satisfied.

LUMINANCE CORRECTION

Figure 3 shows typical luminance curves of a penetration screen (type E21 in this case) as a function of accelerating voltage V_b, beam current being held constant.

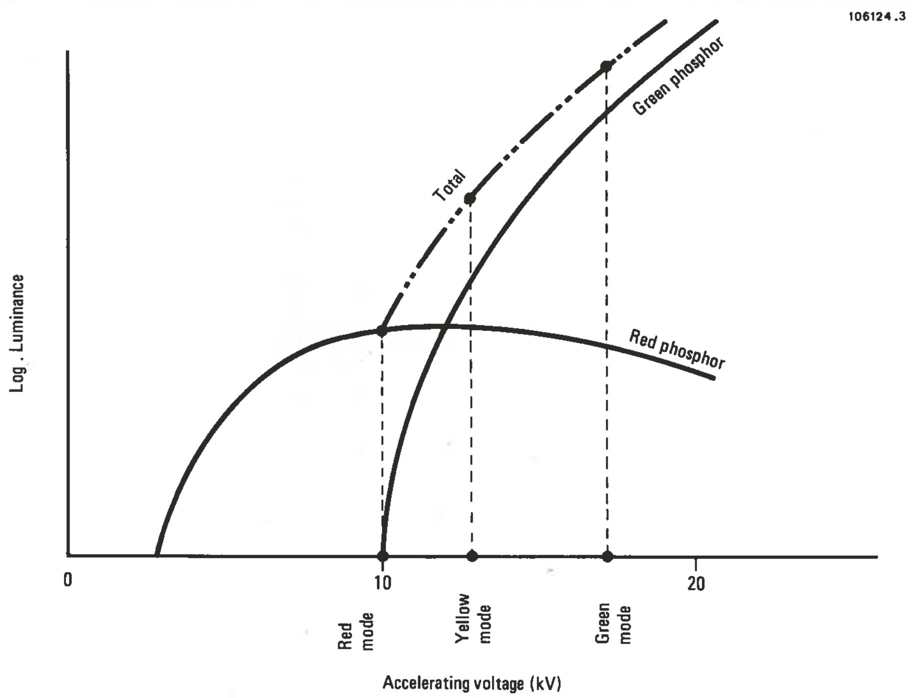


Figure 3 – Typical luminance versus accelerating voltage, at constant screen current (for E21 penetration phosphor screen)

These curves show that to obtain luminances that are approximately the same in different operating modes, the beam current must be higher in the low-voltage mode (red) than in the high-voltage mode (green). Alternatively, the writing speed can be reduced, or the refresh rate increased in the low-voltage mode.

Figure 4 shows the screen luminance as a function of screen current density. The luminances were measured in red and green modes on a standard 625-line/50-Hz television raster, of dimensions 120 x 120 mm.

CORRECTING THE FOCUS

The focusing of the electron beam is affected by the velocity of the electrons, and hence by the accelerating voltage (V_b). In electrostatically focused tubes, the focusing voltages must remain approximately proportional to V_b. In electromagnetically focused tubes, the focusing-coil current must be directly proportional to the square root of V_b.

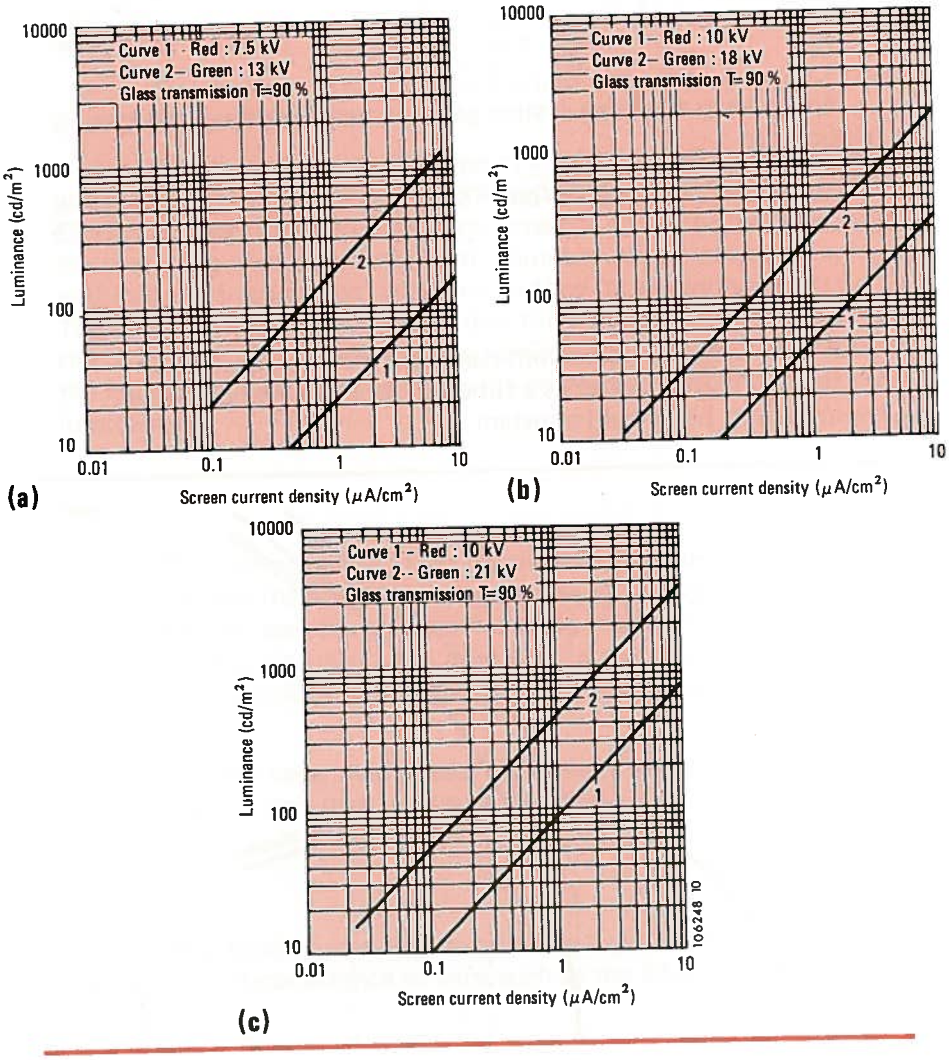


Figure 4 – Typical plots of luminance versus screen current density for the E20 (a), E17 and E21 (b) and E26 (c) screens

DYNAMIC FOCUS CORRECTION

As well as the simple focus correction mentioned above, intended to compensate for the different focusing conditions encountered with different accelerating voltages, dynamic focus correction is often recommendable.

This correction, which is used to reduce the defocusing that occurs between the center and the edge of the screen, is a function of the scanning amplitude (a parabolic law).

Some electrostatic CRTs have an auxiliary electrode, specially intended for this function. For electromagnetically focused CRTs, some yoke manufacturers can supply special double-focusing coils, the low-impedance winding being used for the dynamic correction.

CHOICE OF DEFLECTION YOKE

Comparative measurements have shown that the quality of the deflection yoke can drastically affect tube performance, particularly the resolution at the edges of the screen. Cases have been noted where the resolution was halved, so great care must be taken in selecting a deflection yoke. Suitable models can be obtained from several different manufacturers, including :

OREGA - VIDEOCOLOR, route de Dole, 21100 Genlis, France - Tel. : (80) 31 28 81

THORN - BRIMAR LTD., Greenside Way, Manchester M 241 SN, UK - Tel. : (061) 681 70 72

DISPLAY COMPONENTS, INC., 550 Newtown Road, P.O. Box 488, Littletown, MA 01460, USA - Tel. : (617) 486 35 94

SYNTRONIC INSTRUMENTS INC., 100 Industrial Road, Addision, IL 60101, USA - Tel. : (312) 543 64 44

CELCO, Constantine Engrg. Labs. Co., 70 Constantine Drive, Mahwah, NJ 07430, USA - Tel. : (201) 327 11 23.

WASHBURN LAB. INC, 115 Tompkins Ave., Pleasantville, N.Y. 10570, USA - Tel. : (914) 769 5774.

A WIDE CHOICE OF DEFLECTION YOKE MANUFACTURERS

High-voltage switching circuits

In penetration CRTs, the change in color or persistence is obtained by varying the screen-to-cathode voltage. This can be simply done by switching the screen voltage, keeping the cathode voltage constant. During switching, the CRT is equivalent to a capacitive load, C, this being the capacitance of the fluorescent screen with respect to ground (see Figure 5).

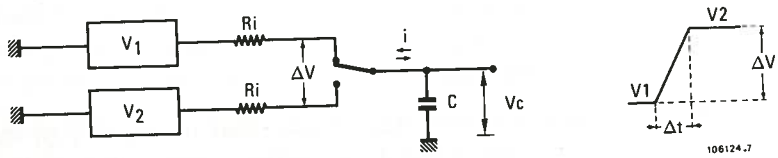


Figure 5 — Principle of high voltage switching

The value of C depends on the tube's dimensions and on the proximity of metal bodies (magnetic shielding around the tube, for example). Typical values are given in the table below.

Tube diameter or diagonal (cm)	Equivalent capacitance (pF)	
	Without shielding	With complete shielding
15 to 25	80	150
25 to 40	100	300
50 to 60	180	500

PRINCIPLE

The switching time (Δt) of the voltage supply depends on the difference (ΔV) between the output voltages, and on the resistance (Ri) of the switching device (see Figure 5).

The power "P" dissipated in the switching device is a function of ΔV and the load capacitance C :

$$P = C(\Delta V)^2 f,$$

where f is the switching frequency with two transitions per cycle.

Example :

Assuming that $\Delta V = 8$ kV, $C = 500$ pF and $f = 1000$ Hz, the power dissipated is $P = 500 \cdot 10^{-12} (8.10^3)^2 10^3 = 32$ watts. With a typical supply efficiency of 30 %, the power required will be 100 watts.

REGULATION OF THE SCREEN VOLTAGE

Each value of screen voltage has three characteristic parameters :

a - The rated value that determines the color or persistence

b - The stability

Low-frequency variations (less than a few hertz) in operating voltage cause image displacement and variations in color or persistence. In practice, the image displacements are more troublesome, and permissible voltage variations must be decided as a function of the intended application.

For example, if a coincidence of better than 1/1000 is required, the relative variations in voltage must not exceed 2/1000.

One means of preventing slow image displacements is to slave the deflection amplitude A, to the high voltage, following the relationship :

$$A = K\sqrt{V}$$

c - Ripple voltage

MINIMIZE THE RIPPLE VOLTAGE

Because of the high resolution available with these tubes, the ripple voltage, which causes resolution losses as it is superimposed on the operating voltage, should be reduced to a minimum. For example, the loss of peripheral resolution is about 10 % for a 16" CRT when the ripple is around 5/10,000 of the operating voltage.

SIMPLIFIED POWER SUPPLIES WITH MODEST PERFORMANCES (see Figure 6)

Two vacuum tubes can be used, V1 as a ballast and V2 allowing the discharge of capacitance C through resistor R1. The resistors R2 and R3 are part of the feedback network of amplifier A, essential for stable operation.

With this type of circuitry, switching times are on the order of a few hundreds of microseconds for a voltage difference (ΔV) of 6 kV, and a capacitance C of 100 pF.

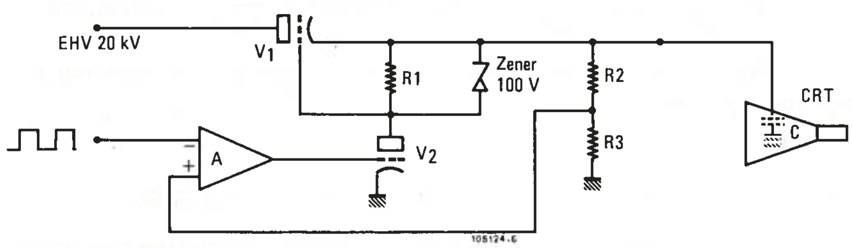


Figure 6 — Principle of a simplified power supply with modest performances.
V_1, V_2 = 6 BK 4, ED 500, etc.

FAST-SWITCHING POWER SUPPLIES

When faster switching is required, the circuits must be capable of dissipating a greater instantaneous power. Figure 7 shows the schematic diagram of a possible fast-switching power supply.

When switch S1 is closed and S2 open, the capacitor C will be charged up to 18 kV. When switch S2 is closed and S1 open, C will discharge to 10 kV. The power is dissipated in the switches.

A common type of switch consists of n transistors or thyristors connected in series. A trigger pulse applied to the transformer primary simultaneously switches on the n transistors or thyristors by means of the n secondary windings. In designing such a switching circuit,

two points are of utmost importance :
– the transformer must be capable of inducing trigger pulses simultaneously in the n secondary windings,
– all semiconductors must be switched on and off simultaneously.

Any component switching out of synchronism with the others will be subjected to the full voltage drop, and the switch circuit will be destroyed. The semiconductors must thus be very carefully selected so as to have identical switching characteristics.

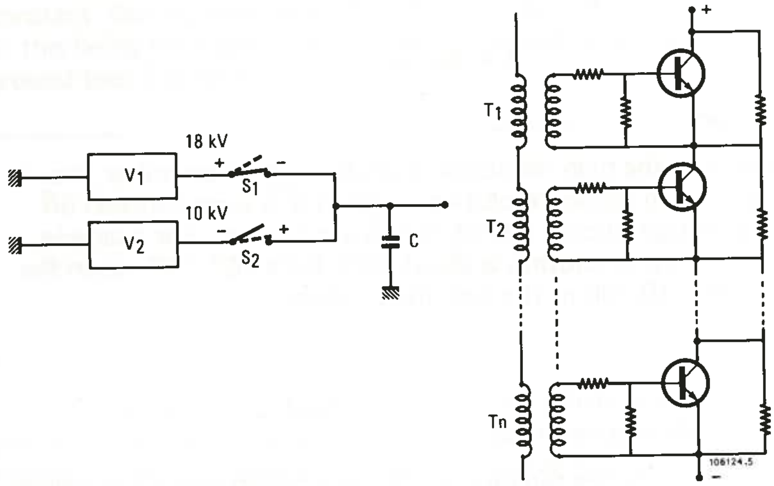


Figure 7 - - Principle of a fast-switching power supply

Example :

For :

$$\Delta V = 8\ \text{kV},\ C = 100\ \text{pF, and}\ \Delta t = 10\ \mu s$$

the peak power dissipated per transition by the switch is :

$$P = \frac{1}{2} C\,(\Delta V)^2\,\frac{1}{\Delta t} = \frac{1}{2} \cdot 10^{-10}\,(8.10^3)^2\,\frac{1}{10^{-5}} = 320\ \text{watts.}$$

As can be seen, this switch must be capable of dissipating a high peak power.

FAST-SWITCHING AND LOW-DISSIPATION POWER SUPPLIES

In this type of power supply, the energy dissipated per transition by the switch is :

$$W = \frac{1}{2} C\,(\Delta V)^2\,(1 - \alpha)$$

where α is a measure of the "idealness", being equal to 1 for a perfect circuit.

A typical circuit, shown in Figure 8, consists of a slow switch (vacuum tube A) connected in parallel with a fast-switching device employing two pulse transformers, permitting the rise and delay times of the transitions to be controlled and considerably reduced.

Transformer T1 delivers a positive pulse of 8 kV, permitting C to be charged from 10 up to 18 kV. When returning to the low voltage, transformer T2 delivers a negative 8 kV pulse, thus dropping C back down to 10 kV.

As the inductance of T1 and T2 are matched to the values of C, this device dissipates very little energy, α values of around 0.85 being quite feasible.

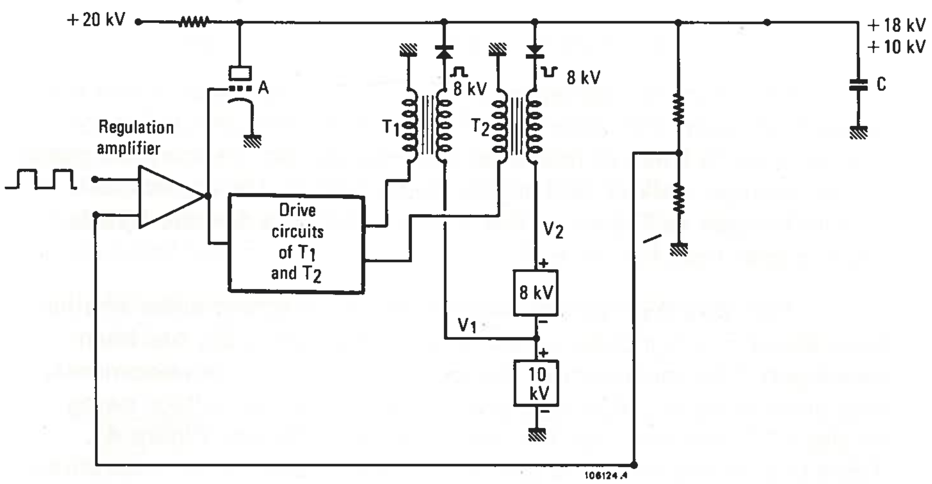


Figure 8 — Principle of a fast-switching, low-dissipation power supply

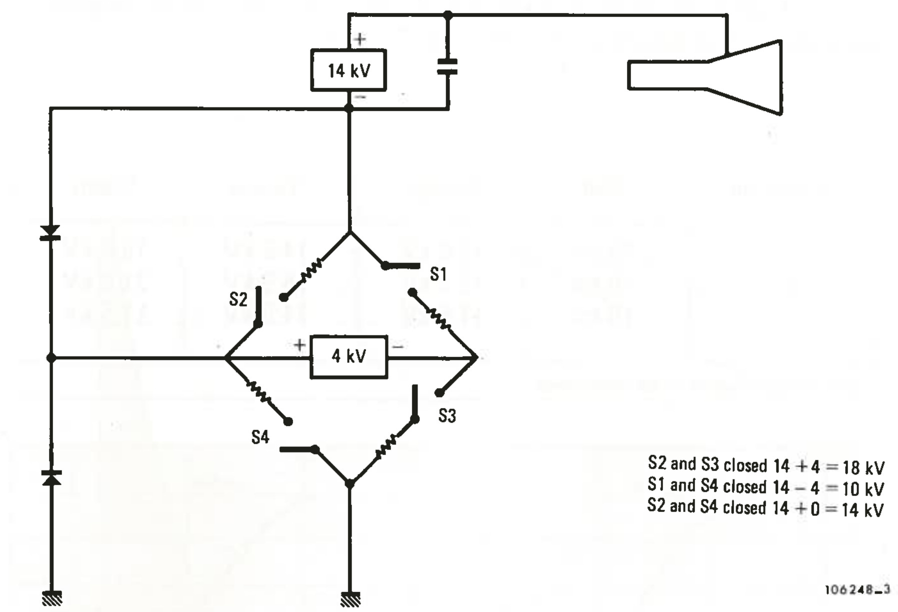


Figure 9 — Operating diagram of a 3-way switching power supply (for example 10 kV, 14 kV and 18 kV). The switches S1 to S4 are composed of several thyristors in series

POWER SUPPLY MANUFACTURERS

Ready-built switching power supplies are offered by several manufacturers, including :

COMPUTER POWER SYSTEMS, 722 East Evelyn Avenue, Sunnyvale, California 94086, USA - Tel. : (408) 738 05 30

VENUS SCIENTIFIC, 399 Smith Street, Farmingdale, New York 11735, USA - Tel. : (212) 895 80 36

KELTRON CORP., 225 Crescent Street, Waltham, Ma. 12154, USA - Tel. : (617) 894 87 00

SOMELEC, 4 Villa Albert Robida, Paris 75019, FRANCE - Tel. : (1) 208 14 09.

THOMSON-CSF
DIVISION TUBES ELECTRONIQUES

Applications and characteristics of the different penetration-phosphor screens

AVIONICS APPLICATIONS : HEAD-DOWN DISPLAYS

Multifunction penetration CRTs can be addressed either by random access or TV raster. The E17 and E26 are high-luminance phosphors with three or four operating modes (red, yellow, and green, or red, orange, yellow, and green), depending on the application. As can be seen in Figure 4, the screen luminance for the E26 is much higher than for the E17.

A NEW HIGH-PERFORMANCE SCREEN : THE E23

For very high performance CRTs with screen areas smaller than about 5 x 5 inches, a new screen structure, E23, has been developed. This incorporates the latest technological developments, and simultaneously offers the advantages of the low voltage swing of the E17, and the high luminance of the E26 (see Figure 4). Table II gives the recommended acceleration voltages for these three screens.

Figure 10 illustrates the relationship between the equivalent wavelength and anode voltage for the E17 and E26 screens.

Table II - Acceleration voltages for different penetration screens

Screen no.	Red	Orange	Yellow	Green
E17	10 kV	12.0 kV	14.5 kV	18.0 kV
E26	10 kV	12.5 kV	15.5 kV	21.0 kV
E23*	10 kV	11.5 kV	14.0 kV	17.5 kV

* Final voltage values to be confirmed.

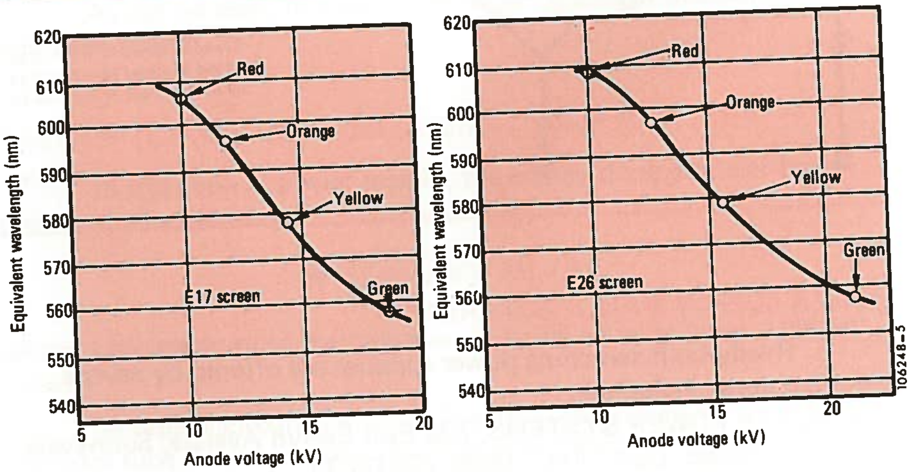


Figure 10 — Equivalent wavelength versus anode voltage for avionics-use screens

ALPHANUMERIC AND GRAPHIC COLOR DISPLAY APPLICATIONS

E20 and E21 are high-luminance, general purpose phosphor screens with four operating modes (red, orange, yellow, and green).

E20 is very similar to E21, but they differ in that E20 operates at a lower voltage (7.5 to 13 kV, instead of 10 to 18 kV) and E21 exhibits enhanced luminance.

E24 is very similar to the E21, with an identical operating voltage range (10 to 18 kV). Its persistance is the same in the red and the green, and E24 gives a higher luminance display than the E21, particularly in the high-voltage (green) mode, but the green is less saturated (see Figure 11).

FOR EXTREMELY HIGH LUMINANCE USE THE E26

Where extremely high luminance must be achieved, the E26 can be used to advantage.

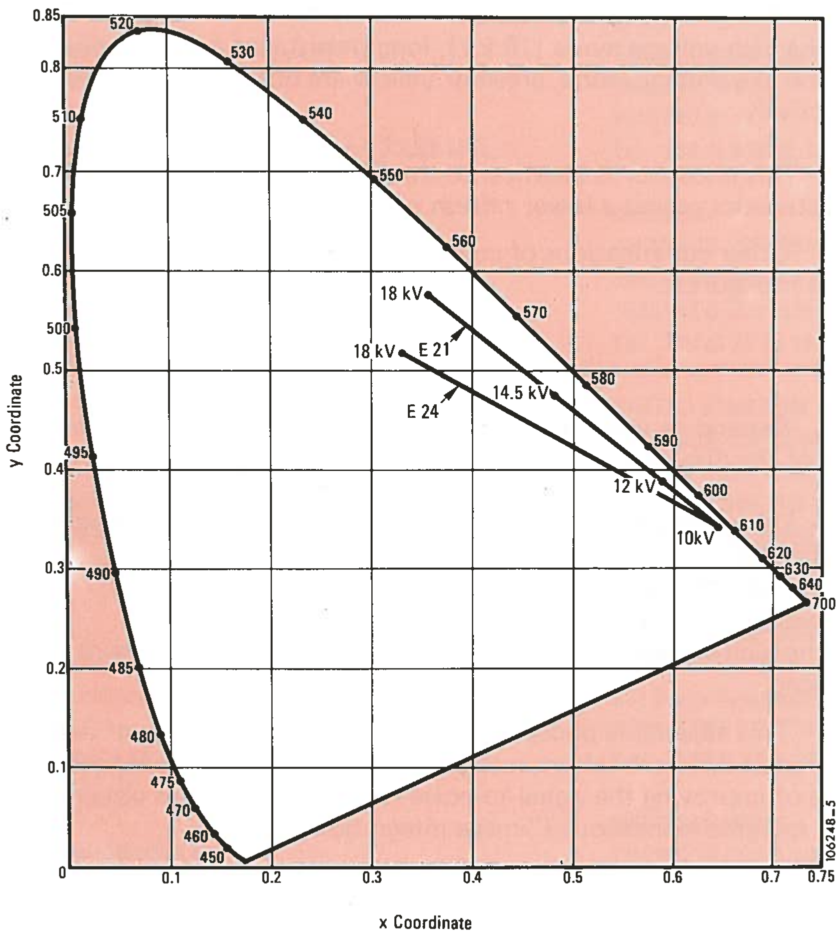


Figure 11 – E21 and E24 CIE chromaticity diagram (1931)

RADAR APPLICATIONS

With multipersistent and multicolor screens, synthetic video information of different origin can be displayed on the same screen. PPI information can be displayed on a phosphor of high persistence, while in TV raster and random access, a non-persistent phosphor with different colors can be used for alphanumeric and graphic information.

Multipersistence screens allow the desired phosphor characteristics to be obtained for each application by simply changing the accelerating voltage :

— at high voltage, a high-persistence orange phosphor for the PPI display ;
— at low voltage, a low persistence phosphor for synthetic computer-generated information.

OTHER PRINCIPAL SCREENS EMPLOYED

Multicolor, Multipersistence Screens

E63 : A GOOD CHOICE FOR SIMULTANEOUS PPI AND SYNTHETIC RADAR IMAGE DISPLAY

E58 — In the low-voltage mode, this screen gives a green color without persistence for synthetic display. In the high-voltage mode, this screen gives an orange color of long persistence.

E71 — This phosphor is very similar to *E58*, but exhibits a brighter and more persistent orange color.

E63 — For simultaneously displayed PPI and synthetic radar images, two operating modes are possible :
— in the high-voltage mode (18 kV), long persistence orange is obtained,
— in the low-voltage mode, green or yellow are obtained, at 9 or 12 kV, respectively.

E64 — This phosphor is identical to the *E63*, except that its antiflicker characteristics permit a lower refresh rate for synthetic radar images.

Other combinations of color and persistence are possible, as shown in Figure 2.

Multipersistence Monochrome Screens

Depending upon the screen voltage during writing, the persistence of the displayed picture elements will be either short or long.

E52 : AN EXCELLENT MONOCHROME SCREEN WITH VARIABLE PERSISTENCE

E52 — This green phosphor can be used in one of two possible operating modes :
— in the low-voltage mode (9 kV), medium-short persistence is obtained ;
— in the high-voltage mode (18 kV) the antiflicker characteristics are enhanced.

This adjustable phosphor can be used for the display of data delivered at different refresh rates, and has also been proposed as a means of improving the signal-to-noise ratio of TV pictures obtained under marginal conditions ("image integration").

RESEARCH AND MANUFACTURING CENTERS

The products presented in this brochure are designed, developed, and manufactured by the Image Tubes and Devices Department.

Research and Manufacturing Center at SAINT-EGREVE, FRANCE (near Grenoble)

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