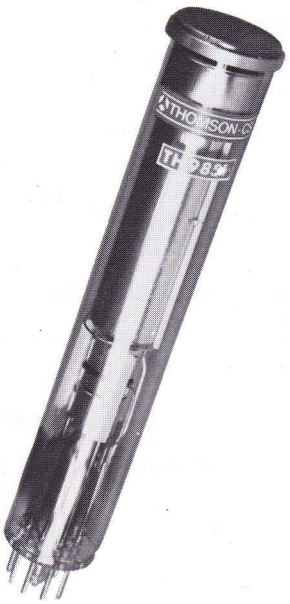
THOMSON-CSF
TUBES ELECTRONIQUES

TH 9875A

1'' PYRICON Infrared Pickup Tube for Thermal TV



- **Pyroelectric target sensitive to very small temperature differences**
- **Extended spectral sensitivy**
- **General construction similar to a 1'' vidicon**
- **Hard-vacuum tube**
- **Operates at room temperature without cooling**
- **Electromagnetic focus and deflection**
- **Low target microphonic signal**
- **Long-life design**

MAIN CHARACTERISTICS

— Infrared-sensitive pickup tube utilizing the thermal radiant energy of objects viewed.

— Wide spectral sensitivity in the infrared range; the sensitivity is in practice limited by the germanium input window transparency. For the TH 9875A, it is optimized in the 8000 to 14000 nm band, which corresponds to the maximum radiant energy of objects at normal ambient temperature.

— Hard-vacuum tube, in which the necessary pedestal current is established by secondary electron generation mode. This results in more stable operation with longer tube life and higher pedestal current for enhanced performance.

— Minimum resolvable temperature lower than 0.2 °C in the case of a black body at 300 K (27 °C).

— Electronic scan - Ease of operation.

— Motion retrieval.

Supersedes TEV 3524

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TYPICAL APPLICATIONS

Thermal TV gives an additional "dimension" to day or night TV operating in the visible range of the spectrum. It shows information that would not be provided by a conventional camera. Operating at European TV standard (625 lines/50 Hz) or American TV standard (525 lines/60 Hz), thermal TV is suited to all existing CCTV equipment (or even broadcast TV equipment). It is easy to superimpose or to add thermal to visible information in the displayed image.

Thermal TV involves the direct and passive viewing of variation or difference of temperature which permits, for example, the observation of objects through light-diffusing media, such as smoke or fog.

In the industrial field, thermal TV permits technical inspection of materials, welds, engine components, electric lines, electronic circuits, and heat exchangers.

In the **instrumentation field**, it is used for spectrography and CO_2 laser interferometry.

In the **security field**. it permits the detection of fire, fluid leakage, the surveillance of technical installations, intruder detection, and camouflage detection.

In the **environmental protection field,** it can be used to detect effluents.

In the **medical field,** it is a diagnostic instrument for cirulation troubles, burns, healing, diverse lesions.

DESCRIPTION

The TH 9875 Pyricon is an infrared-sensitive pickup tube that includes a pyroelectric retina, one side of which faces the scanning electron beam while the other side is backed by a metal electrode used as the signal electrode.

The general configuration of the tube is similar to a vidicon, from which it differs mainly by the input window, transparent to infrared radiation, and by the target, made out of a thin wafer of pyroelectric material.

In the direction normal to its surface, the target presents a spontaneous polarization that varies as a function of its temperature (pyroelectric effect). When an image is projected through the input window, the incident energy is absorbed in the target and produces local variations of temperature, which induce a surface distribution of charges. These charges are compensated for by the scanning beam, which gives rise to the video signal through capacitive coupling with the signal electrode.

At any point on the target, the reading beam permits the detection of temperature variation between two successives scans. Consequently, a still object at a constant temperature cannot be detected when the target has reached its thermal equilibrium. In this case, it is necessary to chop the infrared flux by means of a chopper or to continuously displace the image on the target, either by modifying the angle of view (panning) or by using an optical device (orbiter).

Temperature variations induce either a positive or a negative potential across the target, depending on the direction of variation (increase or decrease of temperature). Unlike in an ordinary vidicon, the electrons deposited by the beam during readout cannot be drained across the target because the target material is non-conductive. These electrons are removed during line flyback by means of secondary emission, obtained by bombarding the target with high energy electrons (about 100 eV). This secondary emission creates a direct current, the pedestal current, that is similar to a dark current.

GENERAL CHARACTERISTICS

Electrical

Cathode ..... Unipotential, indirectly heated, oxide coated
Heater :
— voltage ..... 6.3 V
— current at 6.3 V ..... 95 mA ± 10 %
Minimum preheating time ..... 1 mn
Output capacitance (signal electrode to all other electrodes) ..... < 6 pF
Focusing method ..... Electromagnetic
Deflection method ..... Electromagnetic

Optical

Target :
— minimum useful target diameter ..... 17 mm
— minimum scanning format (overscanning) ..... 18 x 24 mm
Orientation of quality rectangle :
— Horizontal scan parallel to the plane passing through the tube axis and short index pin.
Spectral response ..... See Note 1 and Figure 1

Mechanical

Input window thickness (germanium) ..... 2.1 ± 0.1 mm
Distance from target to window inner face ..... 1.3 to 1.7 mm
Overall length, max. ..... 165 mm
Outer diameter, max. ..... 29 mm
Bulb diameter, max. ..... 26.7 mm
Base (Ditetrar 8 pins) ..... UTE 9 C 15 - JEDEC E 8 - 11
Socket ..... METOX No. 30520
Focus/deflection/alignment coil assembly ..... Thomson-CSF No. TH 7200 B or TH 7203 A
Weight, approx. ..... 60 g
Operating position ..... Any

OPERATING CONDITIONS

(All potentials referred to ground except for the heater)

Maximum Ratings

Heater voltage :		
— minimum	6	V
— maximum	6.6	V
Peak heater-to-cathode voltage :		
— heater negative with respect to cathode	200	V
— heater positive with respect to cathode	120	V
Cathode voltage :		
— flyback, maximum	— 80	V
minimum	— 100	V
— reading, maximum	10	V
Grid g1 voltage :		
— negative bias value	125	V
— positive bias value	0	V
Grid g2 voltage	250	V
Grid g3 voltage	400	V
Grid g4 voltage	500	V
Target voltage (signal electrode) :		
— maximum	0	V
— minimum	— 50	V
Pedestal current (2)	150	nA
Grid g4 current (2), avg.	10	μA
Maximum faceplate irradiance for continuous operation in the 8000 to 14 000 nm range (3)	40	$W.m^{-2}$
Faceplate temperature (4) :		
— storage, maximum	+ 60	°C
minimum	— 40	°C
— operating, maximum	+ 40	°C
minimum	+ 20	°C

Typical Operation

Faceplate temperature : 25 °C
Scanning standard : 625 interlaced lines - 25 images/second
Preamplifier bandwidth : 4 MHz at — 3 dB
Scanned image format : 18 mm x 24 mm; scanned area A = 4.3 cm^2 (5)
Target poling (Note 6 and Figure 2)

Target voltage	— 20	V
Grid g4 voltage (7)	300	V
Grid g3 voltage (7)	200	V
Grid g2 voltage	220	V
Grid g4 current (Ig4) (2)	3 to 5	μA
Pedestal current (Ip) (Note 2 - Figure 5)	100 to 125	nA
Cathode voltage (wrt ground) :		
— during line reading	$\simeq$ 0	V
— during line flyback	— 90	V
Grid g1 voltage (wrt ground) :		
— during line reading : to be adjusted for Ig4 = 3 to 5 μA	— 20 to — 45	V
Cutoff voltage, min.	— 70	V
— during line flyback : to be adjusted for Ip = 100 nA	— 130 to — 170	V
Cutoff voltage, min.	— 180	V

Note : It is recommended :
- to provide for scan-failure protection,
- to perform poling immediately after switching on, in order to stabilize the target potential at the normal value, near the cathode potential (during reading).

Electrooptical Performance

Under the above-mentioned "Typical Operation" conditions :

Average gamma 1

Responsivity measured at the 1st frame (20 ms exposure)
in the 8000 to 14 000 nm range (8) ..... >6 $\mu A.W^{-1}$

Responsivity non-uniformity referred to retina center, measured on centered circle of 13-mm diameter (9) ..... $\pm$ 20 %

Pedestal current non-uniformity (inside a circle of 16 mm diameter centered on the target ..... <20 %

Resolution (10) :

— limiting, in panning mode ($v = 0.3$ cm.s^{-1}) ..... 8 lp/mm
270 TVL for 17 mm picture height

— at 50 % modulation :
- in panning mode (Figure 3) ..... >2.5 lp/mm
- in transient mode at the 1st frame ..... >2.5 lp/mm

Signal current in transient mode at the first frame :

A tube having a responsivity of $S = 6.5\ \mu A.W^{-1}$ submitted to a differential irradiance $\Delta E = 1\ W.m^{-2}$ in the 8000 to 14 000 nm range, delivers a signal current $I_s = 2.8$ nA, at the 1st frame for low spatial frequencies. With a lens matching the 8000 - 14 000 nm range, set at F/1 aperture, the signal current is 1.6 nA for $\Delta\theta = 1$ °C (in the case of a black body at temperature close to 300 K).

Note : The sensitivity increases from 30 % to 50 % when the target temperature is raised from 25 °C to the optimal value of approximately 35 °C.

Minimum resolvable temperature ..... See Figure 4

Microphony, spurious signal (12 to 1000 Hz frequency; 2g acceleration) ..... $<$ 12 nA

BLEMISH SPECIFICATION

Measurement Conditions

The examination of image blemishes is carried out under the following conditions :
1 - The tube is not irradiated.
2 - The beam current (Ig4) and the pedestal current are adjusted to the values mentioned in "Typical Operation".
3 - An adjustment is made to obtain the best focus.
4 - The gain of the video amplifier and the monitor are adjusted so that the 3 lp/mm resolution pattern is clearly visible with a temperature difference of about 10 °C.

The image area is divided into two quality zones :
Zone 1 : area located inside a circle corresponding to an 8-mm diameter on the target.
Zone 2 : area located between Zone 1 and a circle corresponding to a 16-mm diameter on the target.

The blemishes are evaluated by the number (n) of TV lines, in the 625-line standard.

Spots

Both black and white spots are counted.

Actually considered as defects are only those spots giving rise to a signal current greater than 5 nA. Spots having $n < 3$ TVL are allowed unless concentration locally deteriorates the image quality.

TV lines (n)	Allowed spots	
	Zone 1	Zone 2
$n > 12$	0	0
$9 < n \leqslant 12$	1	3
$6 < n \leqslant 9$	3	4
$3 \leqslant n \leqslant 6$	4	5

Other Defects

Other defects are not considered unless their n is greater than 12 TVL or if the concentration of points ($n < 3$ TVL) causes a smudged appearance. These defects are not allowed if the corresponding signal is greater than 3 nA.

TRANSPORTATION AND STORAGE

During transportation and storage of this tube, its temperature must never be allowed to go below — 40 °C, to avoid any risk of damaging the target. Failure to observe this precaution will cause the tube guarantee to become null and void.

PROTECTION AND CLEANLINESS OF THE OPTICAL SURFACES

General

The quality of the image obtained from a pickup tube depends closely upon the cleanliness of its faceplate. In the TH 9875A Pyricon,this faceplate consists of a germanium plate with an antireflection coating on its two faces.

The outer surface of the faceplate must be considered :
— first, as an optical surface that can be altered by scratches, abrasive materials, fingerprints, etc.,
— second, as being located in the image plane or in the near proximity to the image plane, which makes the cleanliness of the faceplate of prime importance.

Protection

For these reasons, it is highly recommended :
— to remove the cap only when putting the tube into the camera, and to put it back on immediately after removing the tube from the camera ;
— to avoid handling tools (pliers, screwdrivers, etc.) in the proximity of the faceplate especially when the protective covering has been removed.

Cleaning

In spite of all of these precautions, if the faceplate appears to be dirty, it is advisable to proceed as follows :
— **to remove particles :** Use a pear-shaped bellows equipped with a soft and non-abrasive bristle brush (such as those commonly used to clean photographic optics) to blow off and sweep up the particles deposited on the faceplate ;

— **to remove fingerprints or other smudges :** Use smooth and non-abrasive paper (for instance, of KLEENEX ® type), soaked with acetone (preferable) or with alcohol, to clean the faceplate. Be careful not to scratch the surface.

Recommended Cleaning Materials :
Paper : code 72032 - PROP chain or equivalent.
Acetone : pure acetone, $\rho 20 = 0.79$ g/ml or "RP" acetone for analysis.
Alcohol : pure ethyl-alcohol (95 or 96 % pure).

SAFETY WARNING for tubes see DOCUMENT DTE 807

NOTES

1 - The spectral response of the tube is determined by the transmittance of the input window.For the TH 9875A, the transmittance is higher than 90 % in the 8000 to 14000-nm range.

2 - The pedestal current is the difference between the currents in the signal electrode when the electron beam scans the mask that borders the retina and when the electron beam scans the retina itself.

During line flyback, for a given voltage applied to the cathode, the pedestal current Ip is function of grid g4 current. Ip increases when this current increases.

The value of the pedestal current can be calculated from the preamplifier output voltage measured on an oscilloscope, assuming that the preamplifier characteristics are known.

Figure 5 shows the pulses to be applied on the cathode and the grid g1 to produce the pedestal.

3 - An irradiance $\Delta E = 40\ W.m^{-2}$ corresponds, for an F/1 lens aperture and $\tau = 0.8$ transmittance, to an exitance of $470\ W.m^{-2}$, i.e., to a source temperature of about 85 °C, in the case of the black body ($\Delta\theta = 58$ °C).

Even if not in use and without a lens, the tube must be protected against intensive infrared irradiance (the sun, for example), which could abruptly raise the retina temperature.

With a lens, point sources of radiation that are too hot can also damage ther target.

4 - The optimal operating temperature is from 25 °C to 35 °C. For lower temperatures, the tube sensitivity progressively decreases.

For temperature higher than 40 °C, the capacitance of the retina increases, which results in excessive lag hence degradation of tube performance. At temperatures near the retina-material Curie point (49 °C), the sensitivity to radiation (i.e., pyroelectric effect) disappears.

5 - In order to obtain stable operation, the target must be entirely scanned. The format 18 mm x 24 m is recommended.

The signal current is proportional to the scanned area; however, the lag and the video band are limiting factors.

6 - Before normal operation, the polarization of the target must be made uniform over its whole surface and oriented so that a temperature increase gives rise to positive charges on the inner face of the retina. This is done by raising the potential of the retina surface to a value of at least 150 V higher than that of the backplate during 20 to 30 seconds. The field between the two faces of the retina is then suppressed before returning to the normal operating conditions.

This sequence (poling) can be executed by negatively biasing the cathode-control grid assembly and simultaneously setting Vg1 for a beam current of 3 μA, while maintaining the signal electrode at 0 V (see Figure 2), to raise the surface of the retina to a potential near that of grid g4 through secondary emission (ratio $\delta > 1$).

The polarization field must be maintained for 20 to 30 seconds and then suppressed by shifting Vg4 down to 0 V. After 10 to 20 seconds, the beam current is switched off and the cathode/control-grid assembly potential returns to its normal value. The beam is then switched on and the tube is operative.

7 - The g3 and g4 voltages must be adjusted to obtain good image uniformity; Vg4 must be higher than Vg3 to avoid having a brilliant zone at the center of the image. Vg3 can be varied from 180 to 250 V, and Vg4 from 250 to 400 V without any change in performance.

8 - The intrinsic responsivity is determined by measuring the signal current delivered by the tube 20 ms after irradiance setting; the zone to be irradiated is limited to a circle of 2-mm diameter centered on the faceplate.

The infrared flux is in the 8000 to 14 000 nm range and the irradiance $\Delta E = 7$ to $10\ W.cm^{-2}$.

The intrinsic responsivity is defined by :

$$S = \frac{Is}{\Delta E \cdot A}$$

where :
Is = signal current in amperes
ΔE = irradiance on input window in W.m
A = scanned area in m^2
S = responsivity in $A.W^{-1}$.

9 - The measurement of responsivity uniformity is made at 4 points of 2-mm diameter located at the crossing points of the defined circle and two perpendicular axes, one of these axes being parallel to the image scanning line.

10 - The resolution is measured as follows :
— **in panning mode** : The image of an infrared test chart is displaced on the retina at a rate of $0.3\ cm.s^{-1}$. Two resolutions are determined : the limiting resolution corresponding to the limit of discernibility and the resolution corresponding to 50 % modulation, by using a storage oscilloscope at the preamplifier output.
— **in transient mode** : The still image of an infrared test chart is projected on the retina through an electronic chopper synchronized to the frame scan. The modulation of the resulting signal, after 20 ms irradiance, is measured at the preamplifier output by a storage oscilloscope.

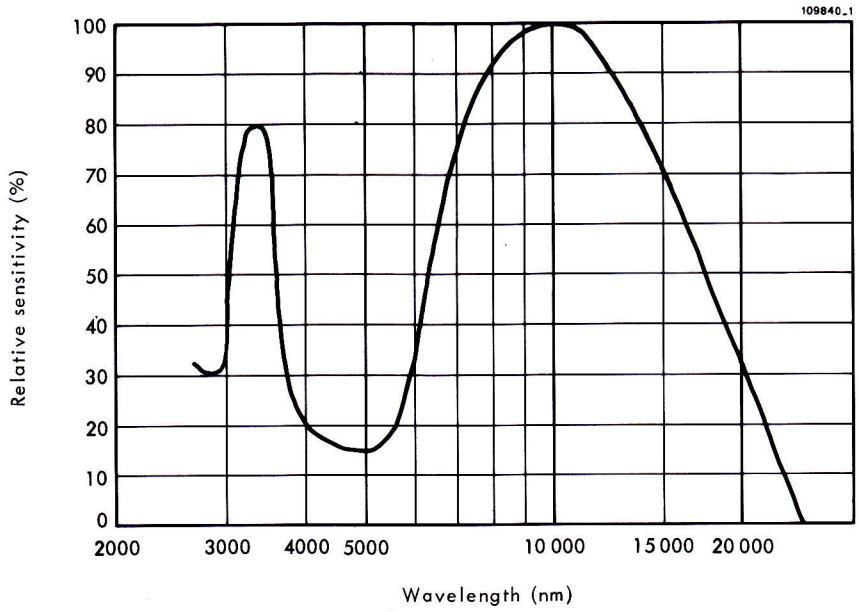


Figure 1 — Tube spectral response

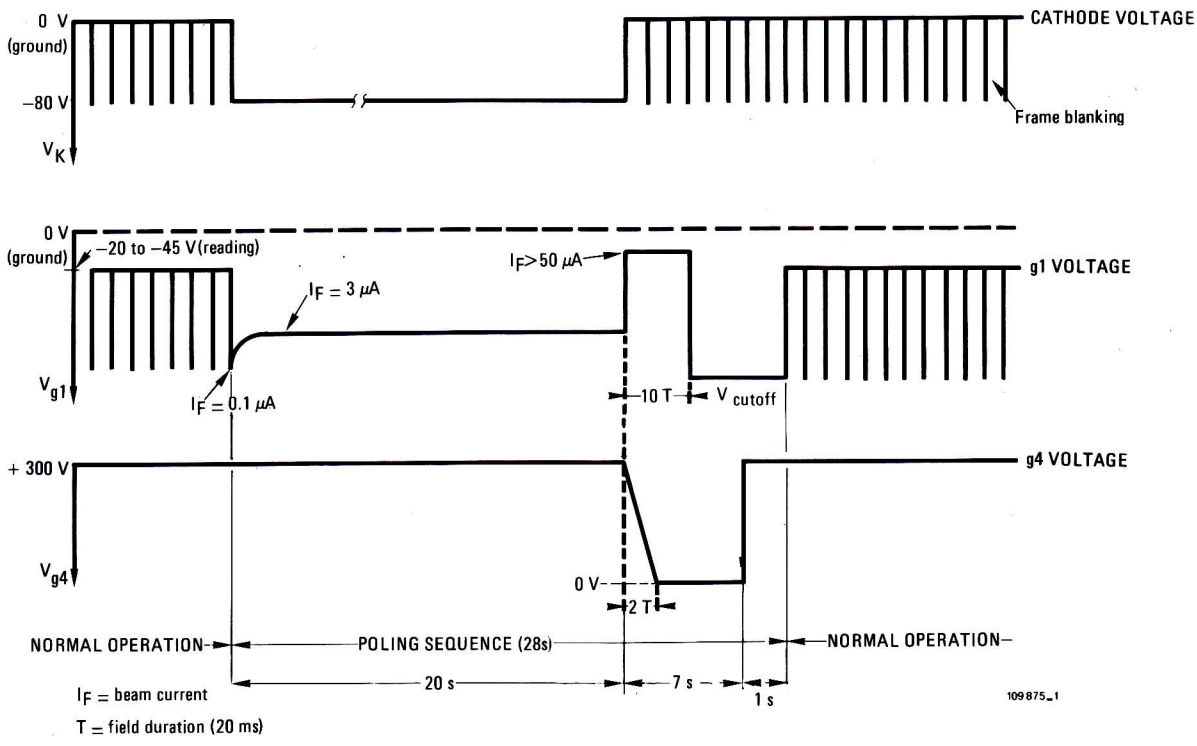


Figure 2 — Timing diagram for target poling by the cathode
(All voltages wrt ground)

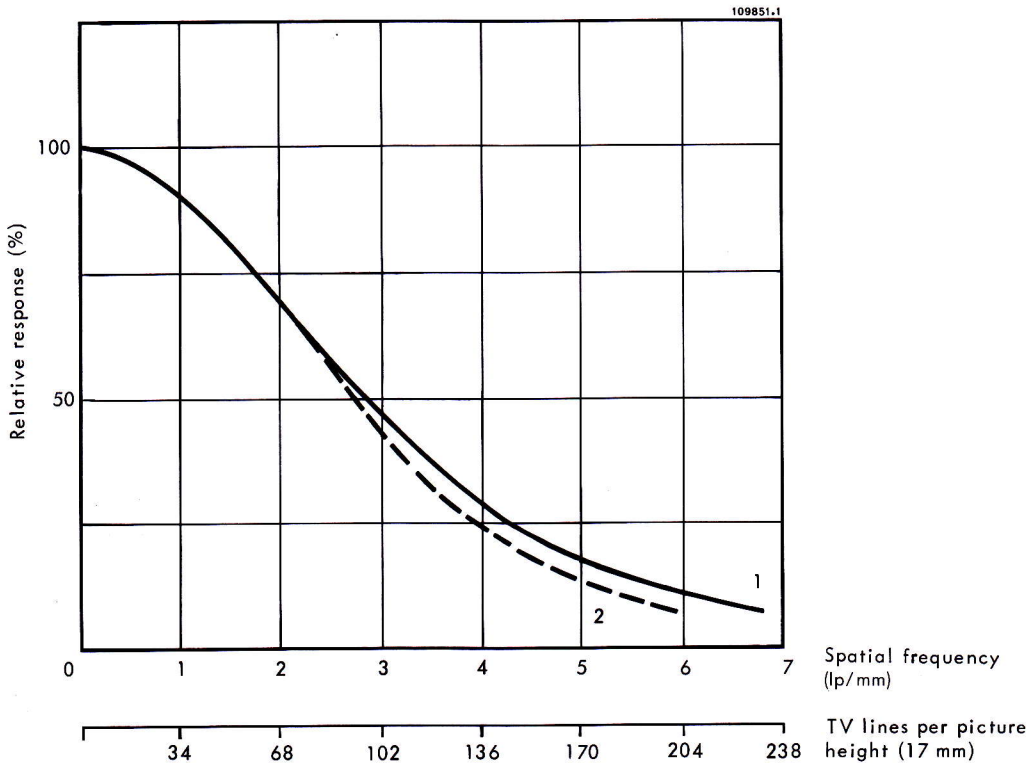


Figure 3 — Typical curve of the Modulation Transfer Function (MTF)

Scanning standard : 625 lines/25 Hz
Bandwidth : 4 MHz
Curve 1 : Measurement made in panning mode at v = 0.3 cm.s^{-1}
Curve 2 : Measurement made in transient mode at the first frame

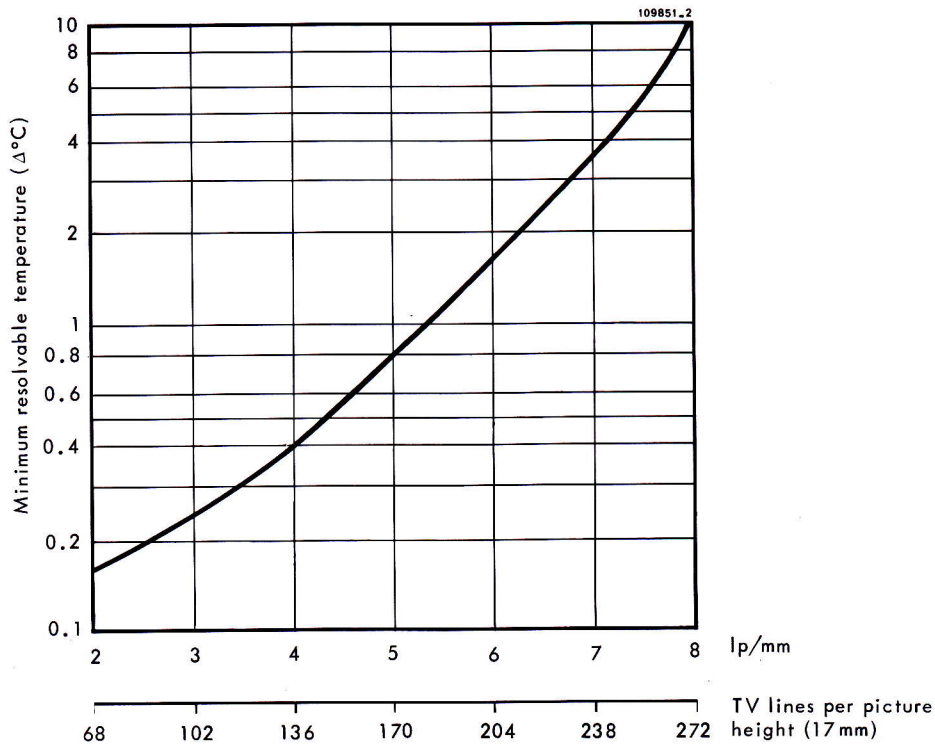


Figure 4 — Typical curve of the minimum resolvable temperature in panning mode at 0.3 cm.s^{-1}

Bandwidth : 4 MHz - Black body near ambient temperature
F/1 aperture number - 4.3 cm^2 scanned area

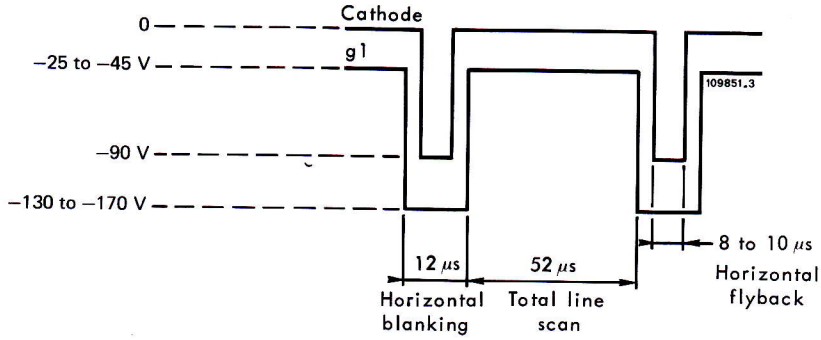
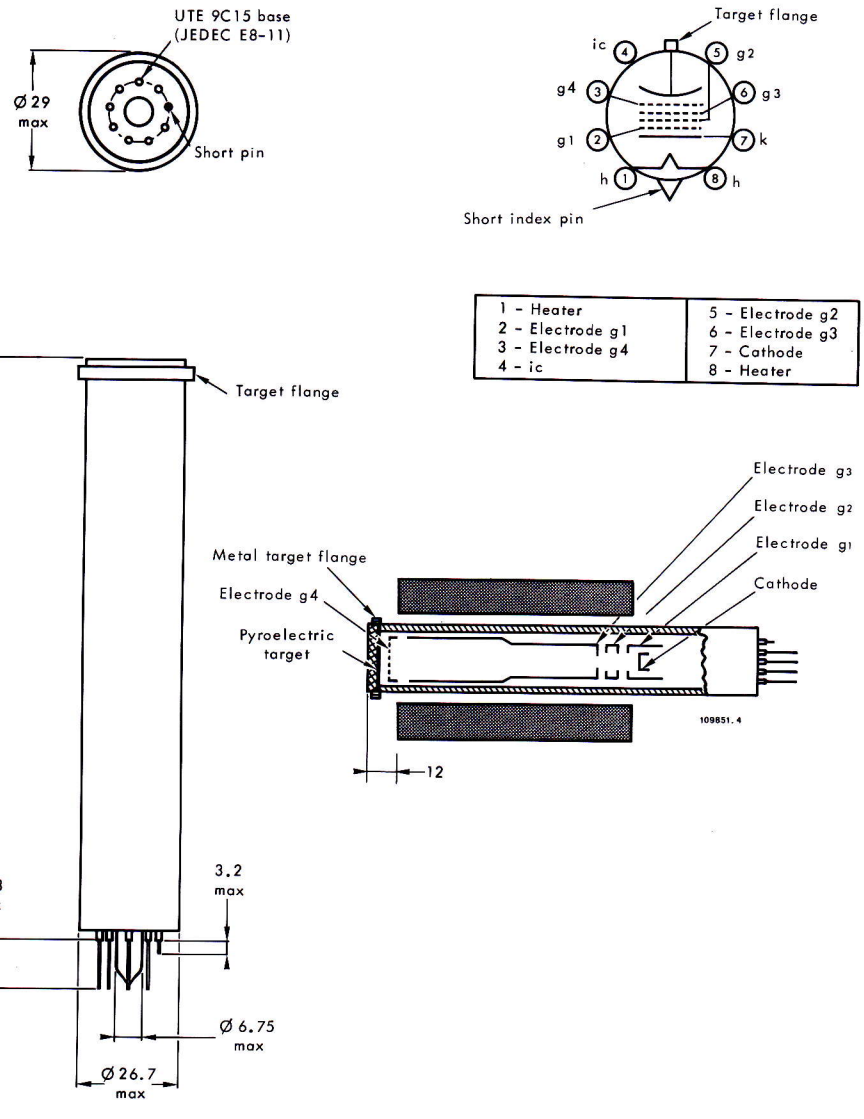


Figure 5 — Pulses to be applied on cathode and grid g1 to produce pedestal during horizontal flyback

OUTLINE DRAWING



Dimensions in mm

INSTRUCTIONS FOR STARTING AND STOPPING A CAMERA USING A HARD-VACUUM PYRICON (Note A1)

The equipment being already adjusted and ready to operate, it is advised to employ the following procedure for applying the voltages and current supplying the tube and the coils and for shutdown.

I - Applying Voltages to the Camera

1. Simultaneously apply :
   - the tube heating voltage
   - the deflection and focus circuit voltages (plus alignment, if required).
2. Set Vg1 to the cutoff voltage* :
   - reading sequence : — 80 V (wrt the cathode)
   - pedestal sequence : — 180 V (wrt the cathode).
3. Put the chopper into service (if desired).
4. Apply the voltages to the other electrodes of the tube.
5. Set Vg1 back to the normal* operating voltage, in the following order :
   - first : reading sequence, adjust Vg1 to obtain $I_{g4} = 3$ to 4 μA
   - after 1 to 2 seconds : pedestal sequence, adjust Vg1 to obtain $I_p = 100$ nA.
6. In case of incorrect poling (appearance of lines, spots, or inverted target image), proceed to execute a poling sequence.
7. Open the shutter (Note A2).

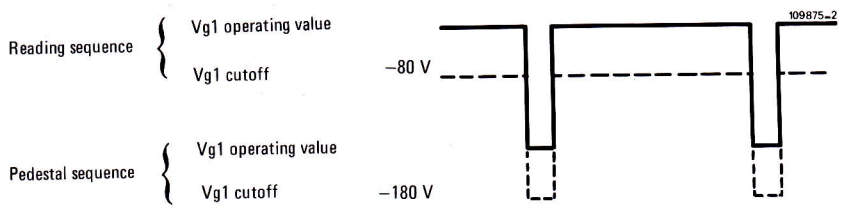


Figure A1 — Values of Vg1 for operation and cutoff, in the reading and pedestal sequences

II - Camera Shutdown

1. Shut the shutter (Note A2).
2. Set Vg1 to the cutoff voltage* in the following order :
   - first, pedestal sequence : — 180 V
   - after 1 to 2 seconds, reading sequence : — 80 V.
3. Maintain these values for a time long enough so that the cathode cannot emit until the voltages of the other electrodes are near 0 V.
4. Switch the other electrode voltages off.
5. Switch the voltages applied to the tube and to the coils (and the chopper when it is used) off.

* See Figure A1.

Note A1 : If these procedures are observed, one can avoid a systematic poling sequence whenever the equipment is put into service.

Note A2 : When the camera is stopped, it is highly recommended to leave the shutter in the "shut" position, so the target cannot be accidentally overilluminated. This shutter can be automatically driven, for the starting or shutdown of the camera.