RCA
Solid State
Division

Electro-Optics and Devices
Application Note
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THE RCA SATICON* VIDICON IN DIAGNOSTIC MEDICAL X-RAY APPLICATIONS

SATICON VIDICON TYPE S81007E

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INTRODUCTION

The SATICON vidicon is a television camera tube of the vidicon family having performance characteristics particularly advantageous in diagnostic medical x-ray applications. It can be used to replace either the antimony trisulfide or the lead-oxide vidicons currently used in these systems (See interchangeability guide at the end of this Note).

The SATICON vidicon combines the better performance features of the antimony trisulfide and lead-oxide vidicons, i.e, the high resolution typical of the antimony trisulfide types and the low lag characteristics typical of the lead-oxide types. However, it does not share the limitations of either type, specifically, the poorer image lag characteristics of the antimony trisulfide vidicons and the poorer resolution of the lead-oxide vidicons. SATICON vidicons retain their performance characteristics through lifetimes typically longer than those of other vidicon types. Additionally, SATICON vidicons feature a very dark photoconductor that effectively reduces the reflection of incident light, and will, therefore, reproduce original intrascene contrast detail with excellent fidelity.

THE PHOTOCONDUCTOR

The SATICON photoconductor is a composite of selenium, arsenic, and tellurium. It is deposited on a transparent, conductive signal electrode that has been evaporated on the inside surface of the glass faceplate of the tube. This signal electrode (or signal plate) is the means by which the photoconductor is connected to the external circuitry (the target connection).

As shown in Fig. 1, that portion of the photoconductor in contact with the signal plate consists of an amorphous layer of selenium and arsenic; the next layer is also selenium and arsenic, but doped with tellurium; the third layer is again selenium and arsenic; and the final deposit is a thin evaporation of antimony trisulfide.

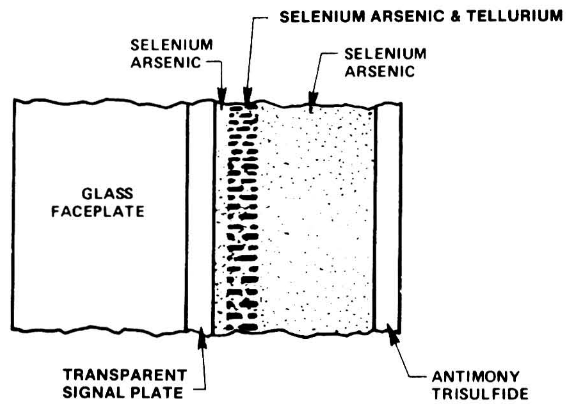

Fig. 1 - Cross section of the SATICON photoconductor and faceplate.

ELECTRICAL CHARACTERISTICS

Electrically, the SATICON photoconductor forms a large-area insulator having a reverse-biased diode at each surface. Fig. 2 illustrates the electrical equivalence diagram of a cross section of the SATICON photoconductor. The

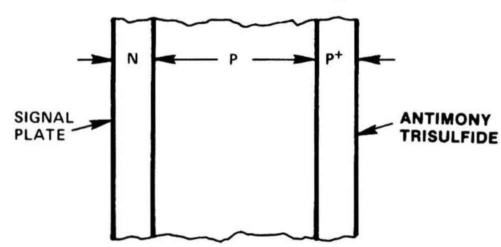

Fig. 2 - Electrical equivalence diagram of a cross section of the SATICON photoconductor.

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junction between the n-type signal plate and the p-type selenium-arsenic-tellurium becomes reverse biased, and the junction between the p-type selenium-arsenic-tellurium and the p+-type antimony trisulfide also becomes reverse biased by the positive potential applied to the signal plate and by the more negative potential developed at the surface of the antimony trisulfide by the scanning electron beam. The n-p diode barrier prevents holes from passing through the layers from the more positive signal plate, while the p-p+ diode barrier prevents the excessive flow of beam electrons. As a result, the SATICON photoconductor has a very low operating dark current. Typically it is less than 0.5 nA per cm^2 at a temperature of 30°C.

An image illuminating the photoconductor will generate electron-hole pairs within the composite materials proportional to intrascene brightness variations. The holes are pulled toward the electron-beam-scanned surface and the electrons toward the signal plate by the strong potential field.

PERFORMANCE CHARACTERISTICS

Light is more fully absorbed in the SATICON photoconductor which is, as evident to the eye, a very dark material. For this reason, the light is not scattered within the material and is not reflected back into the optical system. As a result, the contrast details of even minor brightness variations within the original scene are reproduced with excellent fidelity. These same optical characteristics, and the strong potential field across the photoconductor, which very effectively transfers electron-hole pairs through the material without lateral loss, are the important factors that account for the excellent resolution performance of this unique photoconductor.

The third layer of the photoconductor is made relatively thick to reduce the target capacitance and, thereby, to achieve the lowest possible image lag.

The performance of the SATICON vidicon in diagnostic medical x-ray service is best described in a comparison of this vidicon with the more familiar antimony trisulfide and lead-oxide vidicons at equivalent conditions. In the following illustrations, Figs. 3 through 7, important performance parameters are compared graphically at standard vidicon image and scan formats and at standard operating conditions.

Note: Operating conditions differ substantially in the various camera systems, and it is, therefore, important to make these performance comparisons to a standard reference.

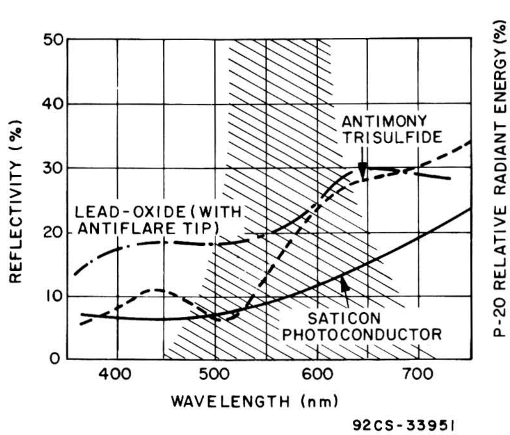

Fig. 3 - Reflectivity. The shaded area is the spectral distribution of the P-20 phosphor of the image-converter screen.

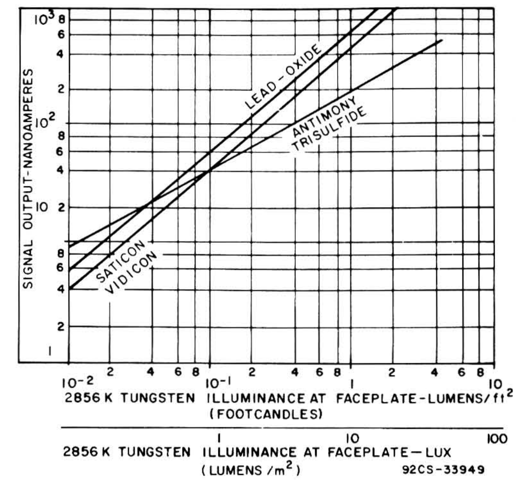

Fig. 4 - Conversion characteristics.

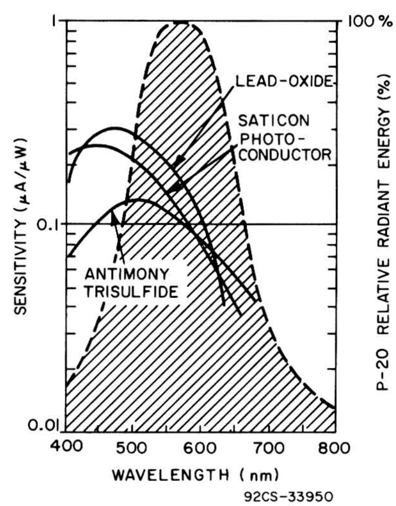

Fig. 5 - Spectral response characteristics. The shaded area is the spectral distribution of the P-20 phosphor screen of the image-converter tube.

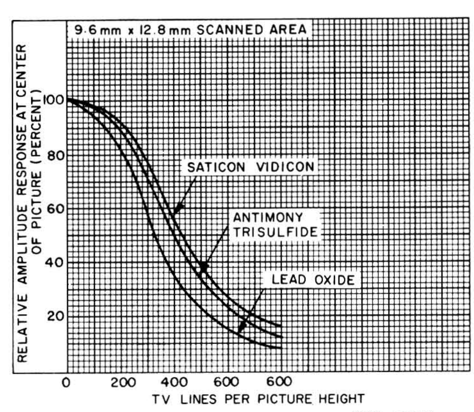

Fig. 6 - Resolution. The amplitude response to the alternate and uniform black-and-white lines at specified spatial frequencies.

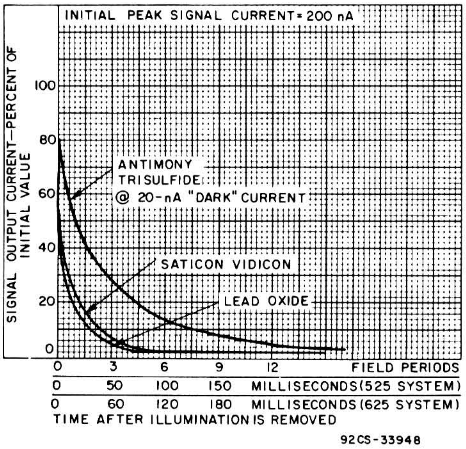

Fig. 7 - Image-lag characteristics. The SATICON vidicon offers a very substantial improvement in image lag over the antimony-trisulfide vidicon, but with sufficient retention to integrate the random noise effects of the image converter.

SET-UP AND OPERATION

The RCA SATICON vidicon may be operated in the various medical x-ray television cameras presently using either the antimony trisulfide or the lead-oxide vidicons. The set-up procedures and operating conditions for the SATICON vidicon are essentially equivalent to those for the other tubes. A review of standard procedures follows.

Notes:
1. Optimum set-up and operation of the vidicon and television camera, and indeed the performance of the total imaging system, is dependent on the proper set-up and operation of each component in the system. Therefore, the optical adjustments, as well as the operating levels of the x-ray and image-converter tubes, should be verified before proceeding with either the vidicon or camera adjustments.
2. Within guidelines established for x-ray exposures, the image converter gain should provide the illumination to the vidicon that will **produce** the required video signal level. With the lens iris (aperture) fully open, the minimum useful illumination on the vidicon should be no less than 0.25 footcandles; typically, an illumination of 1.0 to 2.0 footcandles is available. Refer to step 9, "Operational Signal Levels," in the following procedures.
3. **Refer to the RCA bulletin on the S81007E SATICON vidicon and to the service manual on the camera system for detailed ratings, operating conditions, and performance specifications.**

Set-Up Procedure

Step	Adjustment	Procedure	Function
1	Target Voltage	The SATICON vidicon is operated at a fixed positive target voltage of 50 volts. Note: Target voltage is defined as the voltage difference between the target and the cathode. Since the cathode is not at ground potential in many of the camera systems, and because the beam-blanking signal is often applied to the cathode, the target voltage measurement is made using an oscilloscope and is referenced to the "unblanked" (beam-on) interval of the cathode blanking waveform.	To establish the proper target voltage for the SATICON vidicon.
2	Set-Up (preliminary)	With the SATICON vidicon exposed to a suitable test pattern, bring up the beam to produce picture information. Proceed to adjust beam alignment, optical focus, and beam focus to produce a reasonably good picture. Adjust the input illumination to produce typical picture signal level.	To establish preliminary set-up and operation.
3	Beam Alignment	Adjust the beam alignment controls to the point where the picture does not exhibit lateral movement but rotates about the center point as the beam focus control is turned back and forth through best focus.	To align the electron beam precisely coaxial with the beam-forming and focusing electrodes of the tube and to establish best beam qualities.
	Beam Alignment (Alternate procedure)	Illuminate the SATICON photoconductor to obtain a "token" picture at very low target voltage. Adjust the beam alignment controls to produce the greatest signal level consistent with the best signal uniformity. **Caution:** Never misalign the beam to compensate for nonuniform input illumination. **Reminder:** Reset the target voltage to 50 volts.	

Step	Adjustment	Procedure	Function
4	Beam Focus	Adjust the beam focus control to produce the highest and most uniform resolution.	To obtain best resolution.
5	Image and Scan Format and Scan Linearity	1. Using a suitable test pattern: a. Make the necessary optical system adjustments to center the image format on the SATICON photoconductor. b. Adjust the scan size and centering controls to make the scan format coincident with the image format. Note: The image and scan formats differ significantly in the various camera systems and range from the standard CCTV format having a 3 x 4 aspect ratio of 3/8" by 1/2" to larger, sometimes square, sometimes nearly full target circles. Scanning of an area larger than that specified for the camera system may result in spurious signal qualities in the area perimeters. 2. Using a grating-pattern test signal generator, adjust the scan linearity controls to make the test pattern signals from the SATICON vidicon and the electronic test signal indices coincident on the picture monitor. Note: An adjustment of the linearity controls will usually require the readjustment of the size and centering controls. Note: An error in scan linearity will produce a corresponding error in signal uniformity.	To establish proper image and scan formats on the SATICON photoconductor.
6	Beam Setting, Final	Set the SATICON vidicon beam to discharge a signal level twice the normal operating signal level specified for the camera system.	To establish a beam setting with adequate reserve capability.
7	Beam Alignment, Final	Repeat Step 3	A final beam alignment is advisable following the preceding steps.
8	Beam Focus, Final	Repeat Step 4	A final beam focusing is advisable following the preceding steps.
9	Operating Signal Levels	Place a "phantom" in the x-ray system having the variations in density needed to evaluate the total dynamic range of the imaging system. Now adjust the exposure so that the highlight signal current from the SATICON vidicon produces the peak video level specified for the camera system. Note: Operation at a lower signal current will result in greater image-lag effects and a poorer signal-to-noise ratio, whereas, operation at a higher signal current can result in nonlinear amplification of the video signal. Image detail in the highlight may be reduced or even lost completely at excessively high signal levels. Note: The exposure needed to establish operational signal levels is usually made by adjustment of the x-ray level and/or the image converter gain.	To establish the proper SATICON vidicon and video-system signal levels.

Step	Adjustment	Procedure	Function
9	(continued)	Note: To a significant degree, imaging characteristics important to individual preferences can be provided. With the x-ray exposures and image converter gain **established, a lens aperture adjustment** of just one f/stop will provide that range of illumination to the SATICON vidicon that will optimize image lag (at the larger aperture) or minimize the image-converter noise (at the smaller aperture).	
10	Gamma Compensation	Comment: The picture monitor must display brightness variations proportional to those variations in the original "scene." To achieve this fidelity, the video amplifier in the television camera is usually provided with a gamma compensation control to adjust the signal gain linearity to compensate for the nonlinear transfer characteristics of the picture tube. Light scattering (flare) within the optical system and in the phosphor screen of the image converter tube may additionally limit the reproduction of the original "scene" contrast values. Proper compensation for all system variables is most conveniently achieved by the use of a test "phantom" in the x-ray system having the variations in density needed to evaluate the total dynamic range of the imaging system. The gamma compensation control is then adjusted to achieve the best contrast detail of the "phantom" image as it is viewed on the picture monitor.	To achieve the best reproduction of intrascene variation contrast.

LIGHT BIAS OPERATION

Image lag can be significantly reduced and controlled by the use of light bias. Light biasing is accomplished through the uniform illumination of the SATICON photoconductor that will result in just several nanoamperes of additional "dark" current. Because of this improvement, bias lighting has been featured for some years in color broadcast cameras, and is now in more general use in CCTV. In medical x-ray systems, bias lighting offers an option perhaps unique to that service. While the lowest possible image lag is always desirable, any improvement made in image lag will increase the subjective effects of the x-ray image-converter noise. In the medical x-ray camera, the bias lighting level could be adjusted to offer the best compromise of image lag and image-converter noise, or the bias lighting could be used as an operational control and adjusted to optimize the important requirements for each exposure, thereby satisfying individual preferences in this respect.

Fig. 8 illustrates the improvement in image lag achieved by the use of bias lighting.

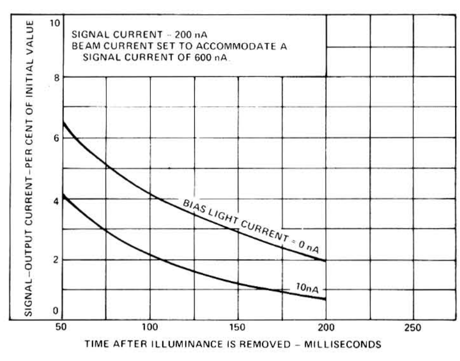

Fig. 8 - Reduction of image-lag effects by the use of bias lighting.

INTERCHANGEABILITY

The interchangeability guide shown below serves as a convenient cross-reference for the more popular vidicon types used in medical x-ray systems. The S81007E SATICON vidicon will replace most of the 25 mm (one inch) antimony trisulfide and lead-oxide types used in that service.

Type to be Replaced	Photoconductor
8541X	Antimony trisulfide type
8000X	Antimony trisulfide type
8864X	Lead-oxide type
E5001 (E5091)	Cadmium selenide
E5063 (E5153)	Antimony trisulfide type
H9362	SATICON photoconductor type
P841X	Antimony trisulfide type
P842X	Antimony trisulfide type
P8021	Lead-oxide type
XQ1041	Antimony trisulfide type
XQ1060	Antimony trisulfide type
XQ1062	Antimony trisulfide type
XQ1072	Lead-oxide type
XQ1240	Antimony trisulfide type
XQ1280	Antimony trisulfide type

For further information on the RCA SATICON vidicon, refer to:

1. "The SATICON Camera Tube," R.G. Neuhauser, RCA Solid State Technical Paper ST-6645.
2. "The SATICON Color Television Camera Tube," R.G. Neuhauser, RCA Solid State Technical Paper ST-6674.
3. The technical bulletin on the S81007E SATICON vidicon, dated December 1980.