RCA
Solid State
Division

Electro-Optics and Devices
Application Note
AN-6994

The RCA Ultricon™
An Improved Vidicon Camera Tube for General Closed-Circuit Television Applications

by C.D. Newcomer

The RCA Ultricon is the most sensitive vidicon camera tube available today for general closed-circuit television (CCTV) applications. It achieves nearly 100-percent quantum efficiency in the visible spectrum with a broad spectral response extending from the near ultraviolet (UV), through the visible, and well into the near infrared (IR). In addition, the Ultricon has new anti-reflective features that very effectively reduce the spurious effects resulting from intense specular highlights within a television scene.

The Ultricon combines new and important performance features with the excellent performance characteristics previously established by RCA silicon-target vidicons:

- High sensitivity
- No after-image effects
- No image burn-in
- Low lag
- High resolution
- Excellent blooming control
- Broad spectral response
- Minimal comet-tailing
- Excellent signal-discharge capabilities
- Low dark current
- Adaptability to special applications

While all of the various vidicons utilize the dual functions of photoelectric conversion and field storage to generate the CCTV video signal, both of these functions are achieved in the Ultricon target in a very different way, and it is this difference in the image-to-signal conversion that produces the Ultricon's unique performance characteristics.

THE ULTRICON TARGET

Construction Features

The Ultricon target is a rectilinear array of silicon diodes having a density of 74 diodes per millimeter in each dimension. (In the standard one-inch vidicon format of 3/8 by 1/2 inch, there are more than 664,000 diodes in the matrix.) The diodes are formed on a wafer of single-crystal silicon by processes familiar in the manufacture of integrated circuits and similar solid-state devices, as follows:

1. The silicon wafer is polished and cleaned.
2. An oxide layer is then formed on one surface of the wafer.
3. Using photolithographic methods, the oxide layer is perforated in a precise hole pattern. The holes are small, just a few micrometers in diameter; each hole is the site of a diode.
4. A p-type dopant is introduced through the holes and into the silicon substrate.
5. Again using photolithographic methods, conductive beam landing pads are formed over the remaining oxide coating in precise registry around each diode site. These conductive pads prevent the scanning electron beam from landing outside the diode sites and, therefore, prevent the surface around the diodes from becoming charged by the electron beam.
6. Additional proprietary processing in the n-type substrate of the silicon wafer results in the near-quantum yield of the Ultricon.

The manufacture of the silicon target involves a series of complex and precise procedures that account for the unique performance advantages of the Ultricon. Because the diodes are small, and because of the landing-pad feature, dark current is low. For these same reasons, the target capacitance and, therefore, image-lag, is also low. Resolution is excellent because there is no lateral leakage of the image charge pattern. And the target has excellent signal-discharge capability.

Target Operation

The target is made to operate in the reverse-biased mode by the positive target potential applied to the front (n-type) surface of the wafer and the more negative potential developed at the rear (p-type) diode matrix surface by the scanning electron beam. Reverse-biased operation results in a depletion region extending from the diode junction into the silicon substrate.

A scene illuminating the front surface of the wafer will generate electron-hole pairs within the silicon substrate proportional to intrascene brightness variations. The minority-carrier holes are swept toward the diodes (the electrons toward the front surface) by the potential field through the wafer. The holes move into the nearest diode site and discharge the established bias in quantum. When the scanning electron beam again restores each diode charge, a signal voltage is developed across the target-circuit load resistor in the camera system.

Performance

The important performance characteristics of various vidicons used in CCTV are compared in the following photographs and graphs. Where applicable, these comparisons were made with the tubes installed in an RCA TC1005 CCTV camera at equivalent operating conditions. The comparisons typify the performance of the 4532/U, a popular one-inch (25-mm) tube (refer to the product bulletin on the RCA Ultricons for detailed operating conditions and performance specifications[1]). Most, but not all, comparisons apply to two-thirds-inch (18-mm) tubes as well.

Printed in USA/10/81

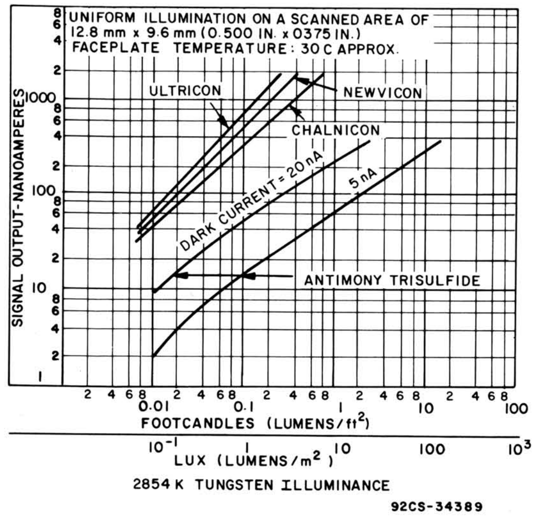

Fig. 1(a) - Conversion characteristics.

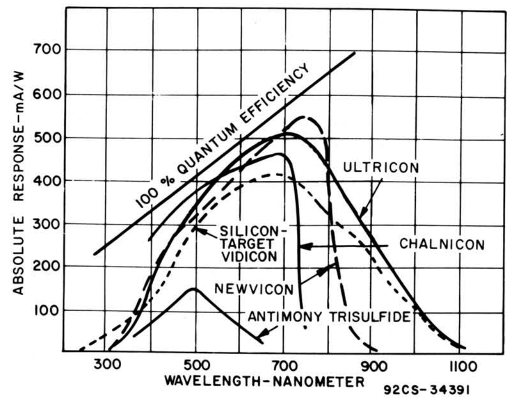

Fig. 1(b) - Spectral response.

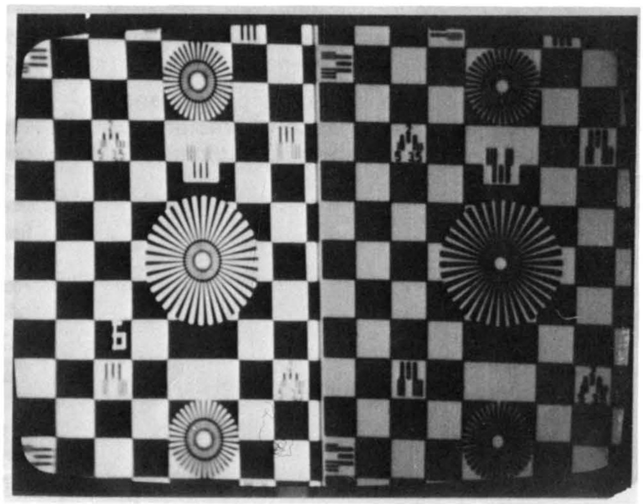

Fig. 1(c) - Sensitivity
A split-screen-monitor comparison of the sensitivity of the Ultricon (left side) and the Newvicon (right side). The test pattern was back-side illuminated by a tungsten lamp. The photograph illustrates the data of Figs. (1)a and 1(b) for the Newvicon and Ultricon.

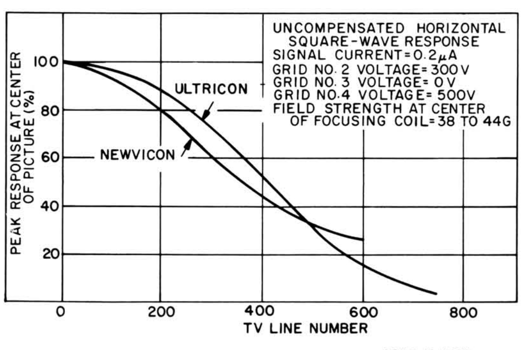

Fig. 2(a) - Resolution
The amplitude response to alternate and uniform black-and-white lines at specified spatial frequences (1" tubes only).

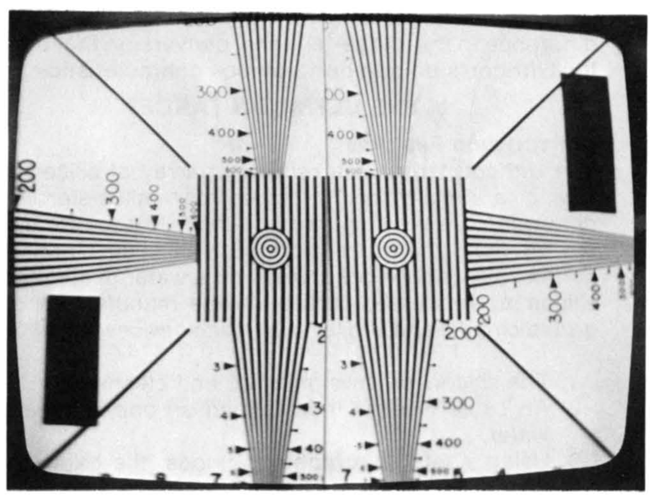

Fig. 2(b) - Resolution
A split-screen-monitor comparison of the resolution capabilities of the Ultricon (left side) and the Newvicon (right side). The lens apertures were adjusted to produce a typical peak signal current of 200 nanoamperes. This photograph illustrates the data of Fig. 2(a) (1" tubes only).

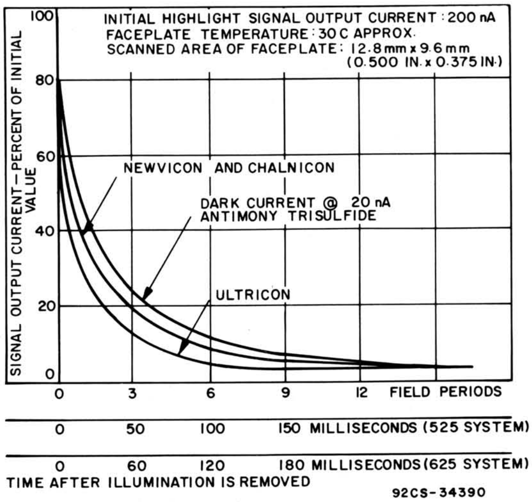

Fig. 3(a) - Image lag.

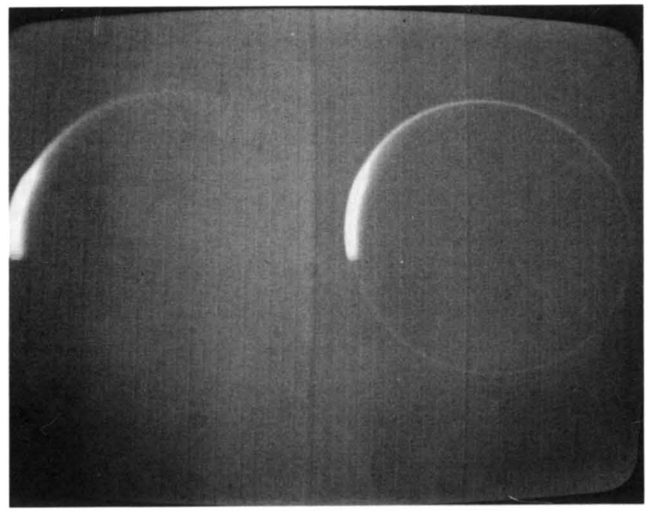

Fig. 3(b) - Comet Tailing

The monitors illustrate the comet-tailing characteristics (the long-term retention of specular highlights) of the Ultricon (left side) and the Newvicon (right side). Typical tubes were exposed to a background illumination simulating night-time conditions (camera system AGC activated). The specular highlights produced peak signal levels just three times the normal operating signal level of 200 nanoamperes.

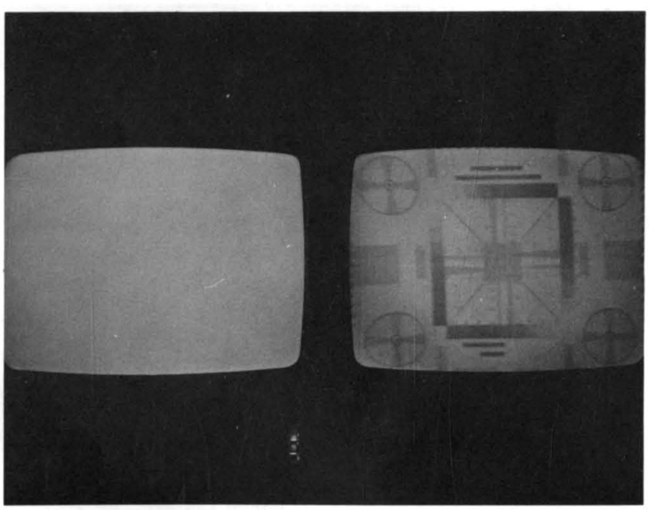

Fig. 4 - After-image

The monitor displays illustrate the after-image characteristics of the Ultricon (left side) and the Newvicon (right side). Typical tubes were exposed to produce 200 nanoamperes of peak signal current for a period of one hour. The camera lenses were then capped. (The camera-system's AGC circuit produced 10x gain.) The photograph was made ten minutes after capping.

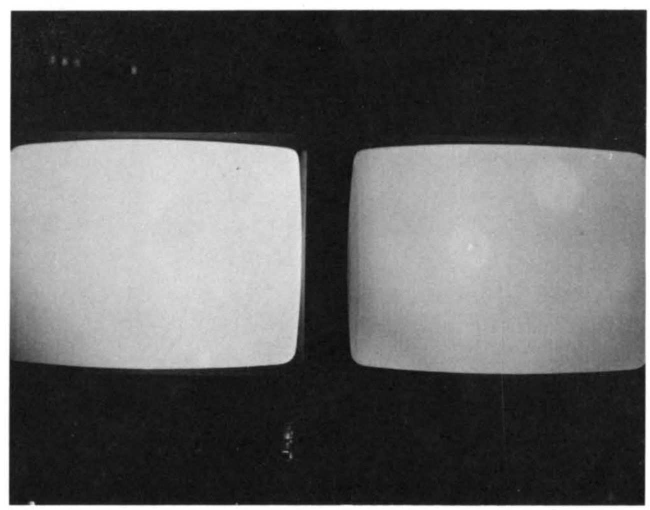

Fig. 5 - Image Burn-in

The monitors illustrate the image burn-in characteristics of the Ultricon (left side) and the Newvicon (right side). For this comparison, typical tubes were equally exposed to an incandescent reading lamp for a period of five hours. The lamp was then turned off while camera operation continued. The photograph was made twenty-four hours later. The cameras operated at standard gain; AGC was turned off.

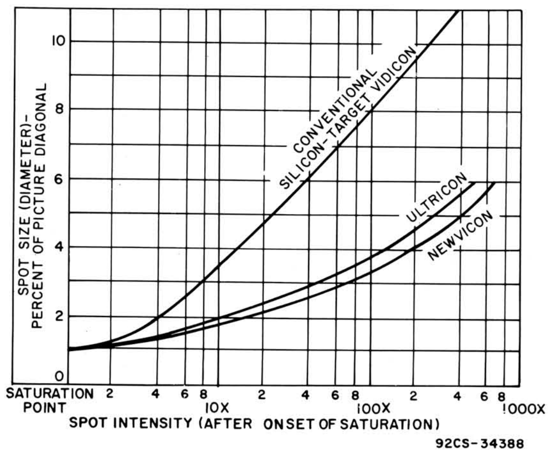

Fig. 6(a) - Blooming at specified overexposures.

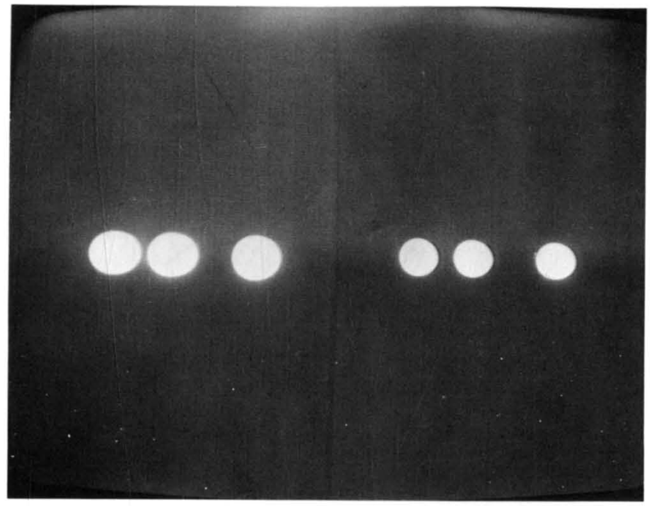

Fig. 6(b) - Blooming
An image of an intense specular highlight within a television scene will "bloom" larger than its true dimension as a function of its brightness. Here, the blooming characteristics of the Ultricon (left side) and the Newvicon (right side) are compared with specular highlights twenty-five times the normal operating peak-signal level. This photograph illustrates the data of Fig. 6(a) for the Newvicon and Ultricon.

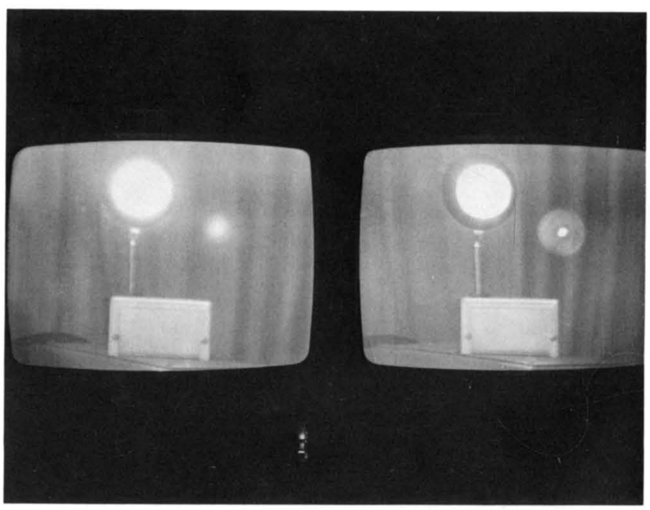

Fig. 7 - Reflection of Highlights
The monitors illustrate the spurious images that result from the reflections of intense specular highlights within a scene. The Ultricon (left side) effectively attenuates these effects. The Newvicon image is displayed on the right side.

Fig. 8 - "Dark Scene" Surveillance
The split-screen-monitor display demonstrates the "dark scene" surveillance capabilities of the Ultricon (left side) and the Newvicon (right side). The scene was illuminated by tungsten lamps filtered to exclude the visible spectrum. The lens aperture (f/stop) was the same for both cameras.

SET-UP AND OPERATING PROCEDURES

The various vidicons made for general CCTV application can usually be used interchangeably in camera systems. The cameras provide common operating conditions and the set-up procedures are standard. The requirements for the Ultricon are essentially equivalent to those applicable to the Newvicon, Chalnicon, Plumbicon, and the various silicon-target vidicons. These tubes are operated at a fixed target voltage and use an auto-iris lens to maintain video signal level for changing scene illumination. Additionally, because these types have linear conversion characteristics (unity gamma), compensation is usually provided for in the camera system to complement the non-linear drive characteristics of the monitor picture tube.

A review of standard set-up procedure follows. Refer to the RCA bulletin on the Ultricons[1] and the service manual for your camera system for detailed operating conditions and performance specifications.

Step	Adjustment	Procedure	Function
1	Target Voltage	The Ultricon is operated at a fixed positive target voltage of 8 to 10 volts. **Note:** Target voltage is the potential difference between the target and the cathode. Since the cathode is not at ground potential in many of the camera systems, and because the vidicon beam-blanking pulses are often applied to the cathode, the measurement of target voltage is made using an oscilloscope, and is referenced to the "unblanked" (beam-on) interval of the blanking waveform.	To establish the proper target voltage for the Ultricon.
2	Set-up (preliminary)	With the vidicon exposed to a suitable test pattern, bring up the vidicon beam to produce picture information. Now 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 vidicon beam precisely coaxial with the beam-forming and focusing electrodes of the tube to establish best beam qualities.
3.1	Beam Alignment (Alternate Procedure)	Illuminate the vidicon to obtain a "token" picture at very low target voltage. Now adjust the beam alignment controls to produce the greatest signal level consistent with the best signal uniformity. **Caution:** Never misalign a vidicon beam to achieve better signal uniformity to compensate for non-uniform input illumination. **Reminder:** Reset the target voltage to 8 to 10 volts.	This alternate beam-alignment procedure will also produce good results.
4	Beam Focus	Adjust the beam-focus control to produce the highest and most uniform resolution. For example, do not peak the resolution in the vertical wedge of the test pattern to the point where it results in a loss of resolution in the horizontal wedge.	To obtain the highest and most uniform resolution.
5	Image and Scan Format and Scan Linearity	Using a suitable test pattern: a. Make the necessary optical system adjustments to center the image format on the vidicon target. b. Adjust the vidicon scan size and centering controls to make the scan format coincident with the image format. Using an electronic test-pattern generator, adjust the vidicon scan-linearity controls to make the test-pattern image coincident with the electronic test signal on the picture monitor.	To establish proper image and scan formats on the vidicon target.

Notes:
1. An adjustment of the linearity controls will usually require the readjustment of the size and centering controls.
2. An error in scan linearity will produce a corresponding error in signal uniformity.

Step	Adjustment	Procedure	Function
6	Beam Setting, Final	Set the vidicon beam to discharge a signal level twice the normal operating-signal level.	To establish a beam setting with an adequate reserve capability.
7	Beam Alignment, Final	Repeat step 3 or 3.1.	A final beam alignment is advisable following the preceding set-up steps.
8	Beam Focus, Final	Repeat step 4.	A final beam focusing is advisable following the preceding set-up sets.
9	Gamma Compensation	**Comment:** The picture monitor must display brightness variations proportional to those variations within the original "scene." To achieve this fidelity, the video amplifier in the television camera has a control (gamma) that permits the adjustment of video-signal gain linearity to compensate for the non-linear transfer characteristics of the picture tube. Compensation is most conveniently achieved by the use of a test pattern having linear steps of gray scale: with the test pattern in place, adjust the exposure to produce a typical video-signal level. Now adjust the gamma compensation control to achieve the best definition of gray scale on the picture monitor.	To achieve the best reproduction of intrascene variations in contrast.

Additional Operating Considerations

The excellent IR sensitivity of the Ultricon allows for unique industrial and surveillance applications. In more general CCTV application, the IR response can substantially extend the low-light-level capabilities of a camera system. However, IR is absorbed or reflected differently (depending on materials) from illumination within the visible spectrum, and it is sometimes important (or desirable) to reproduce intrascene contrast values as they are seen by the eye. The spectral response of the Ultricon is conveniently matched to visual perception by the use of an IR blocking filter. Either the Schott-Jenaer KG3 or the Fish Schurman HA11 may be used; both are available to fit standard lens-filter adapter-rings.

SELECTION AND INTERCHANGEABILITY GUIDE

Table I, the selection guide, and Table II, the interchangeability guide, provide a convenient cross-reference for the popular high-sensitivity heterojunction and silicon-target vidicon types. Refer to the RCA Imaging Devices Catalog for more complete interchangeability and selection information.[2]

Table I — Selection Guide

Type Number* Ultricons	Dimensions and Outlines			JEDEC Base Designation	Heater Current/ Power	Max. Image Diagonal	Focus Method	Deflection Method	Typical Operation (2856 K Source)				
									Sensitivity		Detail Response (4x3 Aspect)		
	Approx. Bulb Dia. (A) mm/in	Max. Overall Length (B) mm/in	Max. Clearance Dia. (C) mm/in		A/W	mm/in			At Dark Current nA	Output Signal nA @ lm/ft²	At Mesh Volts V	Amplitude Response at 400 TV Lines/PH %***	Limiting Resolution TV-Lines
Two-Thirds Inch (18 mm)													
4833/U	18/0.7	107.4/4.23	19.8/0.78	E7-91	0.1/0.6	11.0/0.43	M	M	—	345 @ 0.1	480	60**	450
4833A/U		107.4/4.23	19.8/0.78	E7-91	0.1/0.6	11.0/0.43	M	M	—	345 @ 0.1	480	60**	450
4875/U		103.1/4.06	19.8/0.78	E7-91	0.1/0.6	11.0/0.43	E	M	—	345 @ 0.1	480	50**	425
One-Inch (25 mm)													
4532/U	25/1.0	162.0/6.38	29.0/1.14	E8-11	0.1/0.6	16.0/0.63	M	M	—	720 @ 0.1	480	45	700
4532A/U		162.0/6.38	29.0/1.14	E8-11	0.1/0.6	16.0/0.63	M	M	—	720 @ 0.1	480	45	700
4532B/U		162.0/6.38	29.0/1.14	E8-11	0.1/0.6	16.0/0.63	M	M	—	720 @ 0.1	480	45	700

Notes

*Quality Grades:

/U — Industrial (3rd) Level

A/U — Commercial (2nd) Level

B/U — Premium (1st) Level

**At 200 TVL

***Using RCA P200 slant-line test pattern.

Table II — Interchangeability Guide

TYPE TO BE REPLACED			REPLACEMENT
Type No.	Name	Photoconductor Type	Ultricon Type
1. S4092	Newvicon	zinc telluride, zinc selenide	4875U
2. S4102	Newvicon	zinc telluride, zinc selenide	4875U
3. 4904	Newvicon	zinc telluride, zinc selenide	4875U
4. E5071	Chalnicon	cadmium selenide	4875U
5. XQ1275	S.T. Vidicon	silicon-target	4875U
6. 4875	S.T. Vidicon	silicon-target	4875U
7. 4875/H	S.T. Vidicon	silicon-target	4875U
8. S4075	Newvicon	zinc telluride, zinc selenide	4833U
9. S4113	Newvicon	zinc telluride, zinc selenide	4833U
10. 4905	Newvicon	zinc telluride, zinc selenide	4833U
11. XQ1274	Newvicon	zinc telluride, zinc selenide	4833U
12. E5022	Chalnicon	cadmium selenide	4833U
13. E5072	Chalnicon	cadmium selenide	4833U
14. E5052	Chalnicon	cadmium selenide	4833U
15. 4833	S.T. Vidicon	silicon-target	4833U
16. 4833/H	S.T. Vidicon	silicon-target	4833U
17. 20PE15	S.T. Vidicon	silicon-target	4833U
18. N747	S.T. Vidicon	silicon-target	4833U
19. P8124	S.T. Vidicon	silicon-target	4833U
20. Z7927	S.T. Vidicon	silicon-target	4833U
21. 9231	S.T. Vidicon	silicon-target	4833U
22. S4076	Newvicon	zinc telluride, zinc selenide	4532U
23. 4906	Newvicon	zinc telluride, zinc selenide	4532U
24. XQ1440	Newvicon	zinc telluride, zinc selenide	4532U
25. E5001	Chalnicon	cadmium selenide	4532U
26. E5091	Chalnicon	cadmium selenide	4532U
27. 4532	S.T. Vidicon	silicon-target	4532U
28. 4532/H	S.T. Vidicon	silicon-target	4532U
29. 20PE14	S.T. Vidicon	silicon-target	4532U
30. N736	S.T. Vidicon	silicon-target	4532U
31. E5036	S.T. Vidicon	silicon-target	4532U
32. E5058	S.T. Vidicon	silicon-target	4532U
33. TH9828	S.T. Vidicon	silicon-target	4532U
34. P8125	S.T. Vidicon	silicon-target	4532U
35. P8126	S.T. Vidicon	silicon-target	4532U
36. S1200,1,2,3	S.T. Vidicon	silicon-target	4532U
37. XQ1200	S.T. Vidicon	silicon-target	4532U
38. Z7975	S.T. Vidicon	silicon-target	4532U
39. 9901	S.T. Vidicon	silicon-target	4532U

References

1. Camera-tube data sheet for 4532/U,4833/U,4875/U series, "Ultricon — Improved Silicon-Target Vidicons," RCA Electro-Optics and Devices publication, June 1980.
2. "Imaging Devices," RCA Electro-Optics and Devices catalog IMD-100.

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