THE WX-32193, A NEW 70 mm SEC IMAGE TUBE FOR ASTRONOMICAL APPLICATION

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Abstract

The new SEC image camera tube is designed for astronomical application. Its large target allows a wide viewing angle with excellent resolution and little distortion, as the tube is magnetically focussed. The target is able to store information over several days and with proper cooling integration of weak light signals is possible over several hours. A sequential writing - reading slow scan mode is suggested for most effective application. The window is transmissive far into the vacuum UV-spectrum. Zooming with a fourfold magnification has been successfully demonstrated employing a magnetic lens in front of the image section. The tube construction is ruggedized to withstand the shock and vibration requirements of rocket launch.

Introduction

In this presentation I will give you a brief historical review on the birth of this new product and some details on the mechanical design and material. I will discuss some points on the application and finally will present some performance data.

History

Approximately fifteen years ago, Westinghouse developed its first magnetically focussed and deflected image tube containing as the image forming electrode an SEC (secondary electron conduction) target, the WX-5419B. It was an all-glass tube with an S-20 photocathode. This tube was the forerunner of a series of similar tubes such as the WX-31958 and its UV sensitive sister, the WX-31718, with a MgF_2 window. The latter two were equipped with a square target of 25.4 x 25.4 mm. The image section is a roughly 5 inches long glass cylinder with the window and its photocathode on the one end and the SEC target at the other end. In between are fastened equally spaced accelerator rings which provide the uniform electric field. The image section is sealed to the gun section. Both are inserted in a coil assembly providing a uniform magnetic field parallel to the axis of approximately 70 to 80 gauss. An accelerating voltage of 7-8 K volts must be provided. Near the target on the gun side is the field mesh that operates at several 100 volts and provides the accelerating potential for the scanning beam. Since the secondary emission coefficient of low density KCl is unity at 20-50 volts of the impinging electrons, it is necessary to insert between the field mesh and the target a suppressor mesh with a potential of approximately 17 volts. This tube is shown in Figure No. 1.

Fig. 1 Image Tube, WX-31718

Design

In magnetically focussed tubes the image plane is flat, as there is no crossing of the electron paths in the image section contrary to electrostatic focussed tubes. Hence, distortion and degradation of the resolution at edges and corners in the target image are less. They are caused by distortion of the magnetic field near magnetic tube parts and stray fields at the photocathode or by distortion of the electric field. Both can be kept small by design of tube and camera head.

The SEC target, with a typical gain of 50, is able to collect information over a period of many hours without degrading the information. These advantages over other image devices have caught the attention of the astronomical community and after some improvements the WX-31958, as well as the WX-31718, were well accepted by astronomers both here and abroad.

Five main improvements were introduced. First, the suppressor mesh was abandoned. This avoids target touching during rocket launch and other type shocks. It lowers microphonics, target shunt capacity and avoids the presence of a fixed pattern noise which could sometimes be observed. It also enhances somewhat the resolution and lowers the beam noise. In order to leave the mesh out the secondary emission coefficient of the target surface has to be lowered to less than unity by applying a lateraly non-conducting metal layer on the KCl surface.

Secondly, the gun beam diameter is decreased by diminishing the limiting aperture of the gun triode. The third improvement is the introduction of a light shield at the cathode heater assembly of the gun in order to avoid unwanted dark current from the photocathode and walls. The fourth major improvement is a reliable sealing technique of an ultraviolet light transmissive window-like MgF_2. In Figure 2, this technique is illustrated. A gold foil, thin enough not to transfer any stress due to the different expansion of Kovar and MgF_2, is electron beam welded to the Kovar flange.

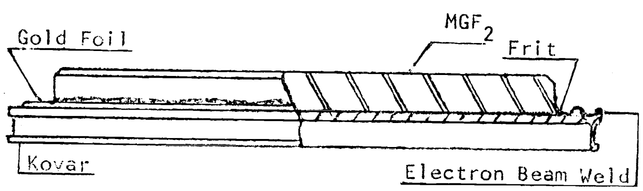

Fig. 2 MgF_2 Window Assembly

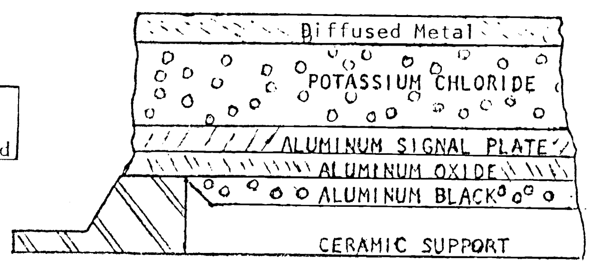

Fig. 3 SEC Target

The MgF_2 window is then frit-glassed to the foil. A stress releasing distance between the beam weld and the frit seal of 6 to 7 mm is recommended. Lastly, both tube types were ruggedized to withstand rocket launch. The WX-31718 was successfully launched by rocket as well as by balloon and recovered undamaged and operational. The WX-31958, only useable in the visible spectrum range, is used extensively in ground observation.

In spite of the successful application of these tubes, there was still a burning desire for further improvement. An increased target area would allow a larger viewing angle and by using a ceramic image section the ratio between outer diameter and useful inside, could be made more favorable with improved ruggedness. An increase in target area considering rocket launch, is not an easy task. The target construction is seen in Figure 3. On a ceramic frame onto which a 500 Å thick supporting aluminum oxide film is attached a 500 Å thick aluminum film is evaporated as the signal plate. Onto the aluminum the image forming low density KCl layer of 10-15 μm thickness is evaporated with a finely distributed metal film on top of it.

The resulting targets, which are more than four times in area as the previous targets used in the WX-31958 and WX-31718, are able to withstand the required shock and vibration of rocket launch. The useable target area is 50 x 55 mm. The target frame is made out of alumina in order to match the expansion co-efficient of the target substrate film. Since it is an insulator it aids in reducing the target shunt capacitance.

This new image tube, designated WX-32193, is shown in Figure 4.

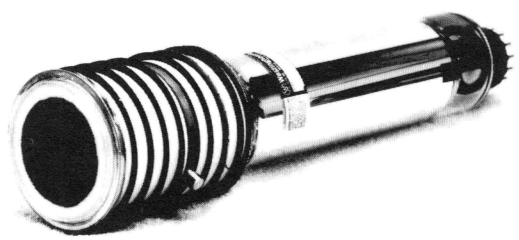

Fig. 4 New Image Tube, WX-32193

The cross section of the tube with gun, heat shield, mesh, target and image sections, is seen in Figure 5. The image section comprises the ceramic rings, accelerator rings, exhaust exits, antimony injector, alkali generators and on top the photocathodes.

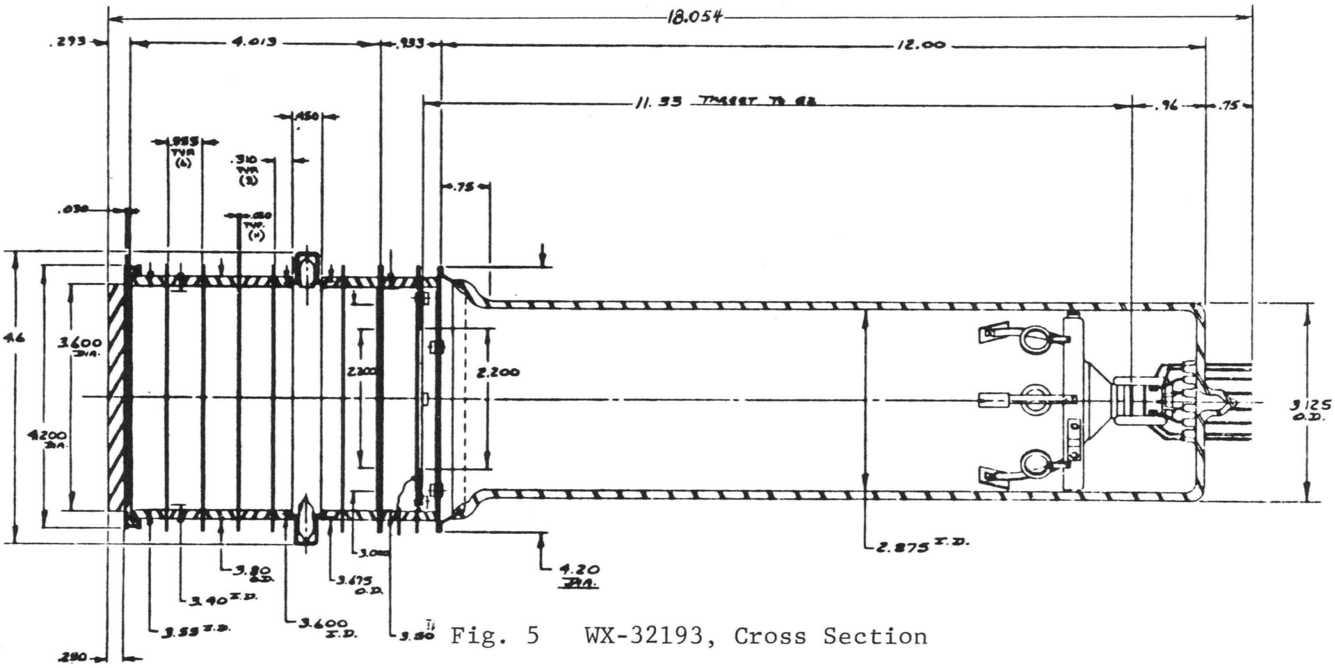

Fig. 5 WX-32193, Cross Section

The window can be made of glass or MgF_2. The tube can be customized with various photocathodes such as S-20 with extended red response, bi-alkali of the type K-Cs-Sb or its oxidized version with enhanced red response or solar blind types such as cesium telluride (Cs-Te). In Figure 6 there is shown a typical spectral response of a K-Cs-Sb type cathode on MgF_2 with a 90% white transmissive chromium underlayer. The metal layer chemically separates the alkalies from the MgF_2. The quantum efficiency of this photocathode ranges between 10 and 20% in the spectral range of 1150 Å to almost 5000 Å.

Application

Astronomers became interested in this line of tubes as early as ten years ago when the television exploration of distant objects in the universe became more and more feasible. It was only natural that astronomers focussed their attention again on these tube types when the Large Space Telescope (LST) venture came into consideration.

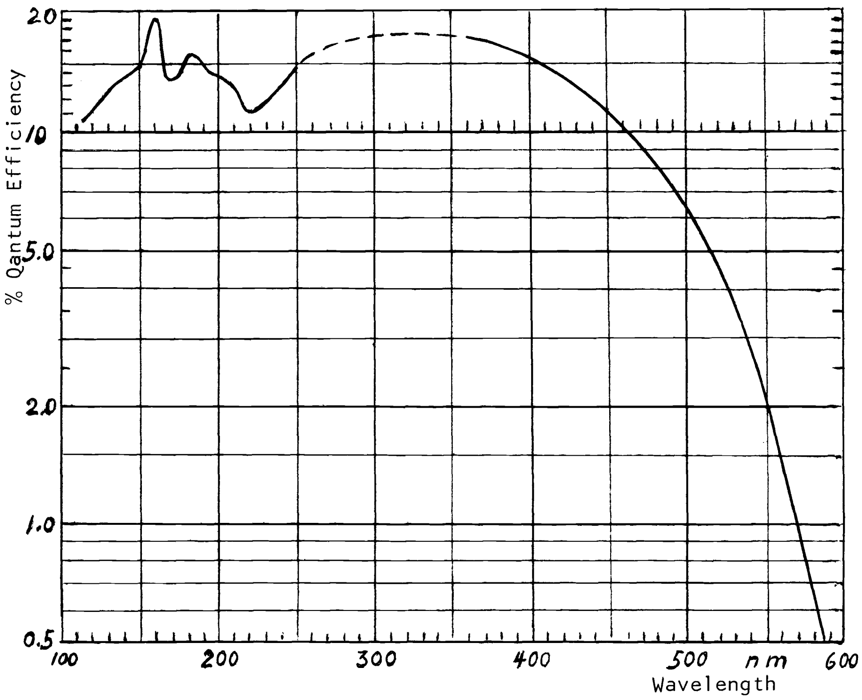

Fig. 6 Spectral Response of K-Cs-Sb On MgF_2

The initially projected telescope with a 3m mirror and a focal length of 45 m was expected to exhibit a limiting spatial frequency of 6 x 10^6 cycles/radian at a wavelength of 5000 Å over a field of view of about four arc minutes. With an f-number of 15 the image is 53 mm wide. The limiting spatial frequency corresponds to 138 cycles/mm. Counting one picture element for each half cycle one arrives to 14,600 picture elements/ width. No available image sensor is able to deliver a resolving power of this magnitude. The best UV sensitive sensor at the time was the WX-31718 with a resolving power of 20 LP/mm with 50% modulation. This tube would accommodate 1,000 picture elements for a width of 25 mm. Using this tube without change of the focal length would diminish the resolving power tremendously but would diminish the viewing angle only by two. On the other hand, to make full use of the resolving power of the telescope, the focal length has to be increased to approximately 300 m. The f-number is then 100 and the field of view would be 0.29 arc min. The new tube with a target 50 x 55 mm would increase the viewing angle to 0.6 arc min. with roughly 2000 x 2000 picture elements. Another important aspect to consider is the dynamic range. The range can be increased in SEC targets, either by making the KCl layer thinner or increasing the density of the KCl. Both will somewhat sacrifice the speed of the target. This means no restriction for astronomical application since slow scan mode operation is used.

PERFORMANCE

The intended application of the WX-32193 is mainly in a slow scan operation. The test and performance data given are arrived in a test operation with a 30 sec. frame time and approximately 1800 scan lines per raster height. The tube may also be used with standard TV scan rates in which case approximately 500 scan lines are used. However, resolution may be somewhat reduced and lag more pronounced. If the spot diameter of the scanning beam is of the order of 25 μm, 2000 scan lines are needed to readout the target of 50 mm height. With standard TV rates, because of fewer scan lines, the beam has either to be defocussed, which lowers the performance, or the beam has to be wobbled. In a magnetic focus coil system, some wobbling occurs; however, using a permanent magnet system the beam focussing is improved. The latter system gives somewhat higher modulation. In Figure 7 a typical amplitude response is shown with 40% modulation at 18 LP/mm. In a permanent magnet system, 50% was easily achieved. Figure 8 shows a typical transfer characteristic with 1000 pA saturation current and in Figure 9 we see a typical target gain versus target voltage. The background current per integration time is of the order of 3 pA/min. at a tube temperature of approximately 35 C. With proper cooling it will go down. The residual signal in the third field is typically 2%. In Figure 10 there is shown the modulation where the last group represents 1832 TVL/RH and the first 916 TVL/RH.

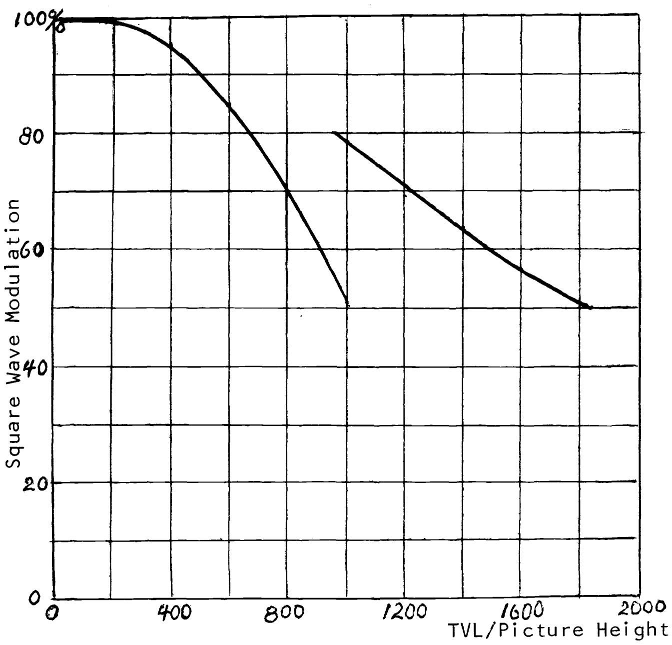

Fig. 7 Amplitude Response

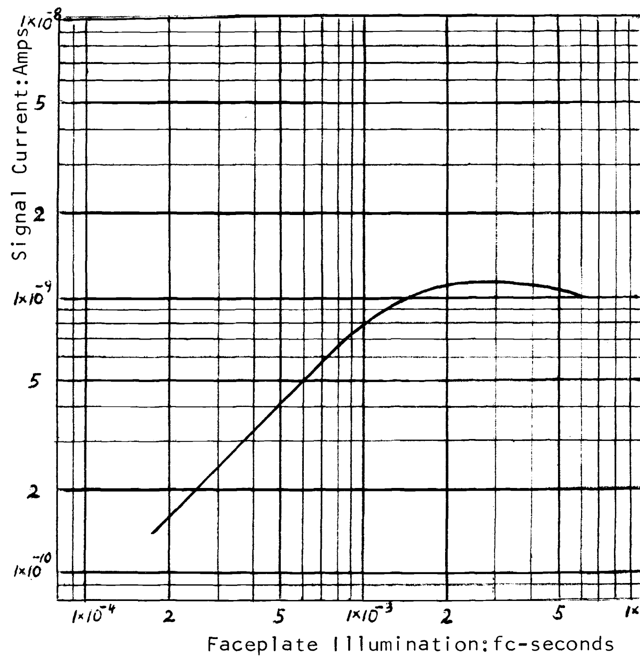

Fig. 8 Transfer Characteristic

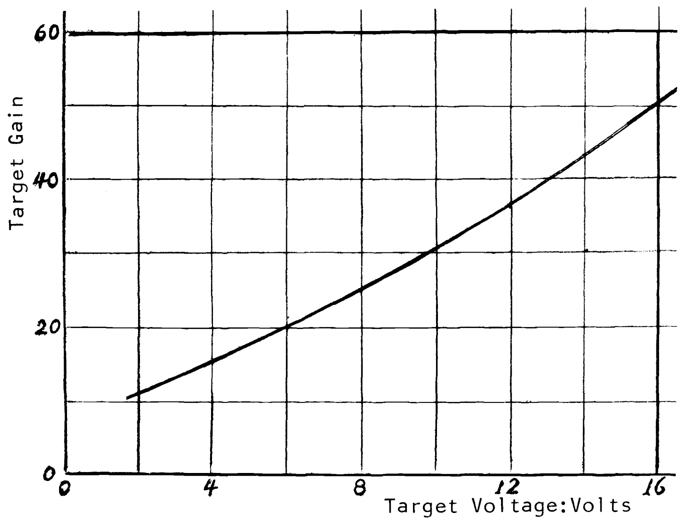

Fig. 9 Target Gain

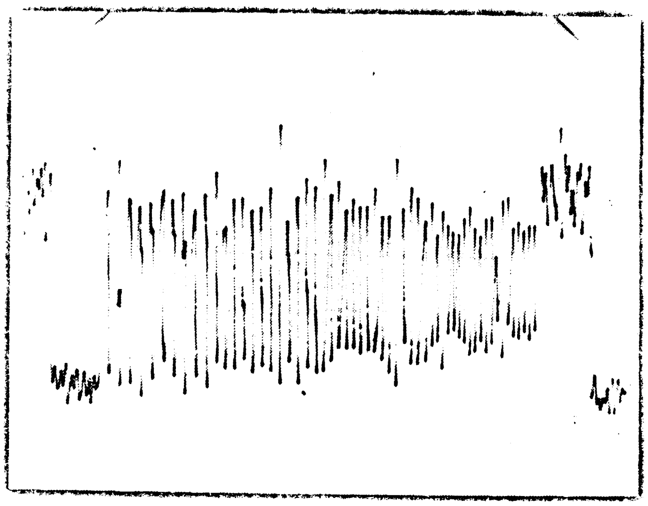

Fig. 10 Modulation at 916 - 1832 TVL/RH

Figure 11 shows the percent modulation for two spatial frequencies, 9.28 cycles/mm and 18.56 cycles/mm for different pixel as well as line numbers. The modulation in the center is of the order of 50% and better. Figure 12 shows the enlarged part of a monitor photograph clearly showing the individual pixels of a size 25 x 25 μm.

In some applications it may be advantageous to zoom in a particular part of the image. Experiments have shown that an image magnification of 3 or even 4 is possible with a magnetic lens in the magnetic focus coil. In Figure 13 the monitor screen photographs with an image magnification of unity and 3.4 are shown. The corresponding MTF curves are shown in Figure 14. The MTF is not very great in this tube because these experiments were conducted with very early tube models, however it shows basically the improvement achieved by zooming.

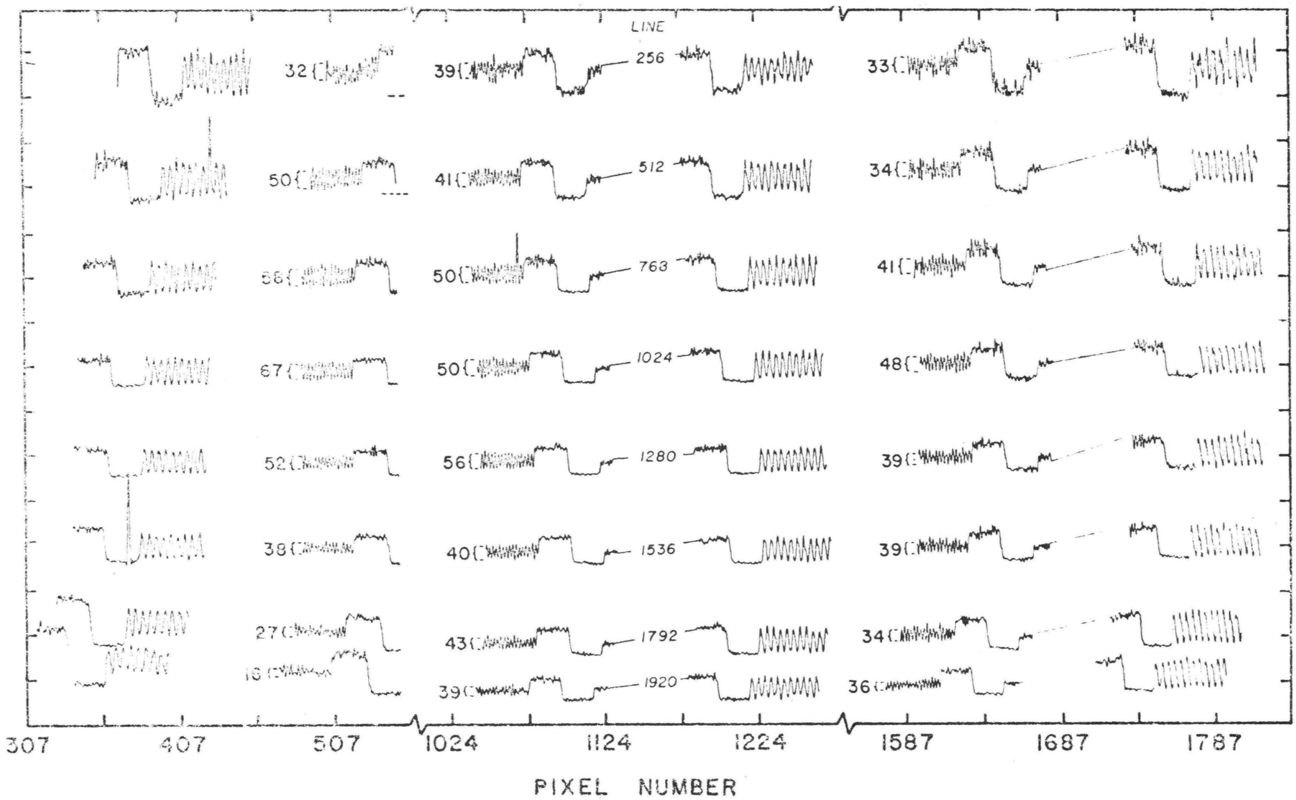

Fig. 11 Modulation at Various Pixel Elements

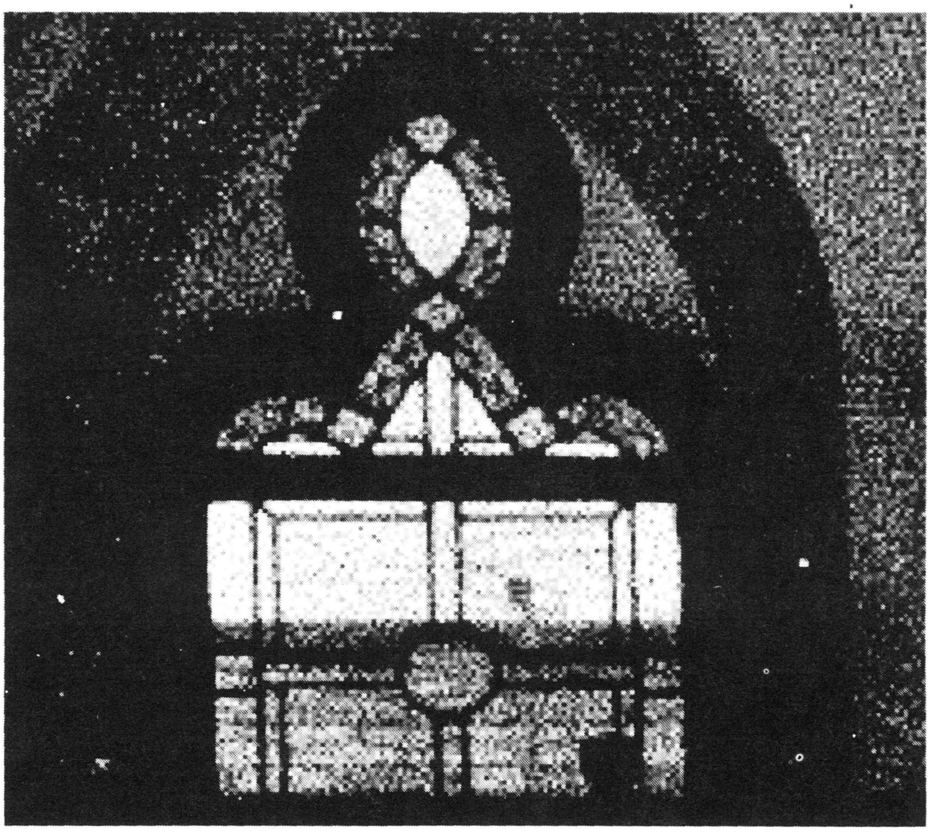

Fig. 12 Enlarged Monitor Image

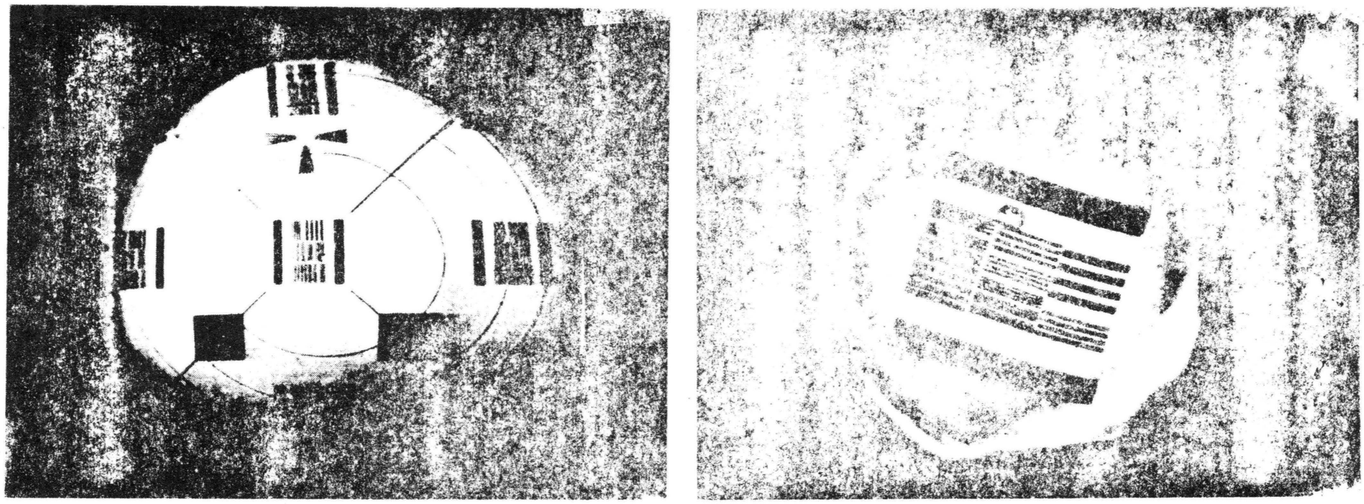

Fig. 13 1:3.4 Zooming

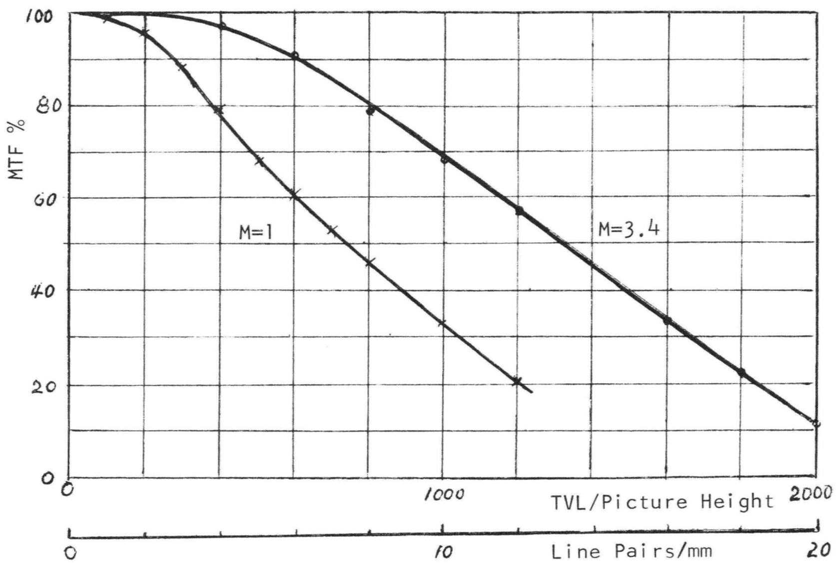

Fig. 14 Modulation With Zooming

Acknowledgement

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References

1) Build, Test and Document (50) Each Tubes WX-32193
Final Report: Nas 5-23387, I&G Tube Division, Westinghouse
2) Electronic Magnification for Astronomical Camera Tubes
Final Report: Nas 5-20511, Westinghouse R&D Center, J. Vine, J. R. Hansen, J. Pietrzyk
3) Large, High Resolution Integrating TV Sensor For Astronomical Applications,
Final Report: Nas 5-20833, Princeton University, L. Spitzer, J. Lowrance