MIMO-MINIATURE IMAGE ORTHICON*

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Summary—*A miniature image orthicon, known as the "Mimo" tube, has been developed for use in airborne television equipment. Its reduced size and power requirements permit a substantial reduction in the dimensions and weight of the pickup-tube camera. The Mimo incorporates an improved mounting technique and employs additional fine mesh screens in front of the photocathode and target for the purpose of shaping the electric fields and simplifying operation. The resolution and signal-to-noise ratio of the Mimo approach that of the larger image orthicon at high light levels under carefully controlled conditions. Performance considerations as a function of the tube size are discussed.*

Introduction

MILITARY applications for a miniature television camera have prompted the development of a pickup tube considerably smaller than any of the tubes in commercial use. At the same time, the aim was to approximate the performance of the larger tubes. Of all of the well-known types of pickup tubes, the image orthicon because of its high sensitivity and high signal level output was most suited for scaling down. Accordingly, a miniature image orthicon called the "Mimo" tube has been designed for use in airborne television equipment.[2] Figure 1 shows a comparative photograph of the Mimo tube and an image orthicon.[†]

The mechanism of operation of the Mimo tube is essentially the same as the image orthicon whose cross-sectional diagram is shown in Figure 2. The optical image is projected on the semi-transparent photocathode laid on the inside surface of the glass envelope. The resulting photoelectrons are focussed by the uniform magnetic field, and they land at high velocity on the thin, semi-conducting glass target. Since the secondary emission ratio of the glass is greater than unity, a positive charge pattern is built up on the glass corresponding to the light and shade in the optical image. The target screen collects the secondary electrons from the glass and serves to limit the maximum potential to which the glass may rise. A low-velocity beam scans the other side of the glass target and deposits sufficient electrons in the positive areas to drive the glass down to the potential of the thermionic cathode of the gun. The conductivity of the glass is so chosen that the charge is con-

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[1] A. Rose, P. K. Weimer, and H. B. Law, "The Image Orthicon—A Sensitive Television Pick-up Tube", *Proc. I. R. E.*, Vol. 34, pp. 424-432, July, 1946.

[2] R. D. Kell and G. C. Sziklai, "Miniature Airborne Television Equipment", RCA REVIEW, Vol. VII, No. 3, pp. 338-357, Sept., 1946.

† Throughout this paper the term "image orthicon" will refer only to the tube described in Reference 1.

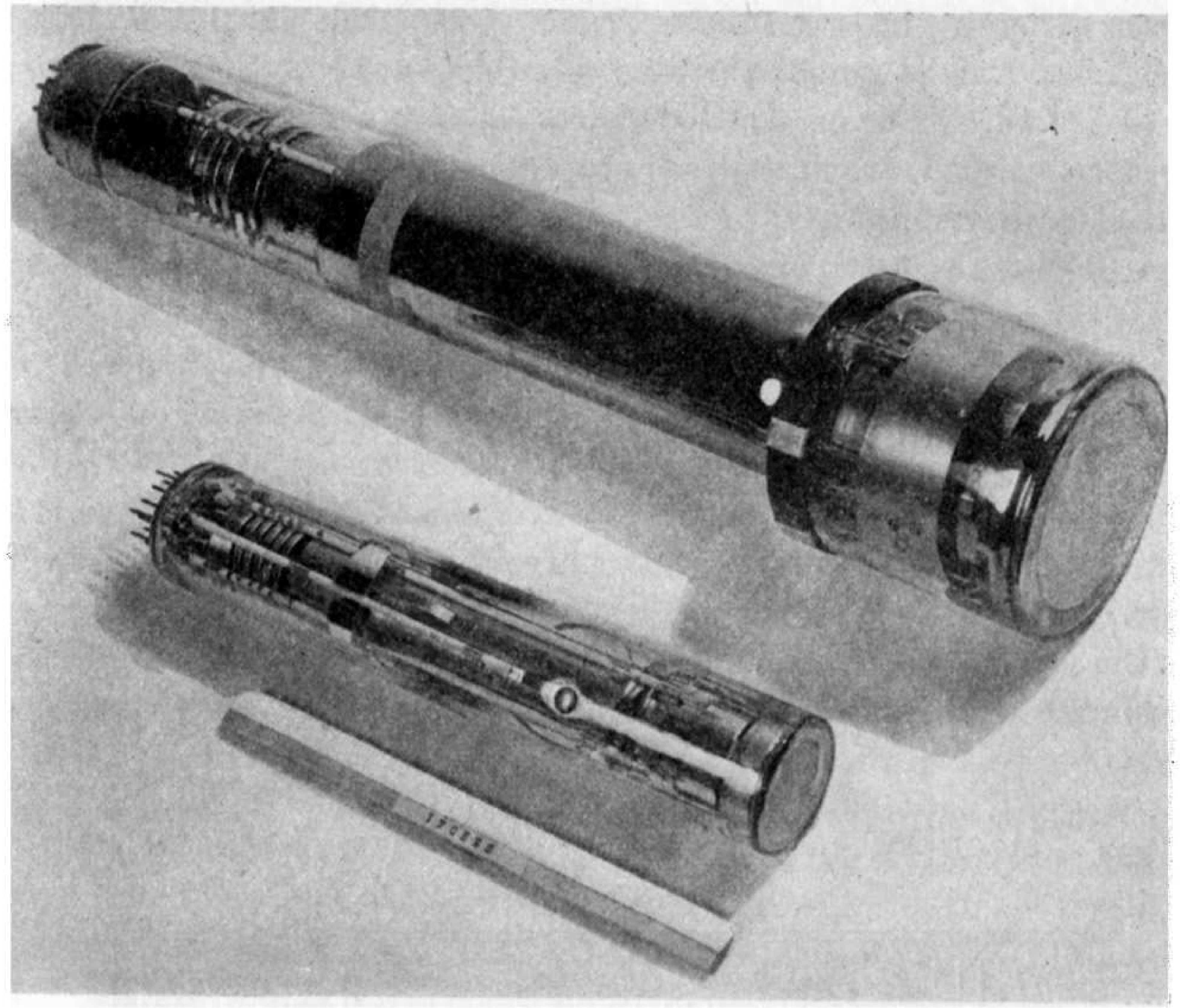

Fig. 1—Comparison of the Mimo tube with an image orthicon.

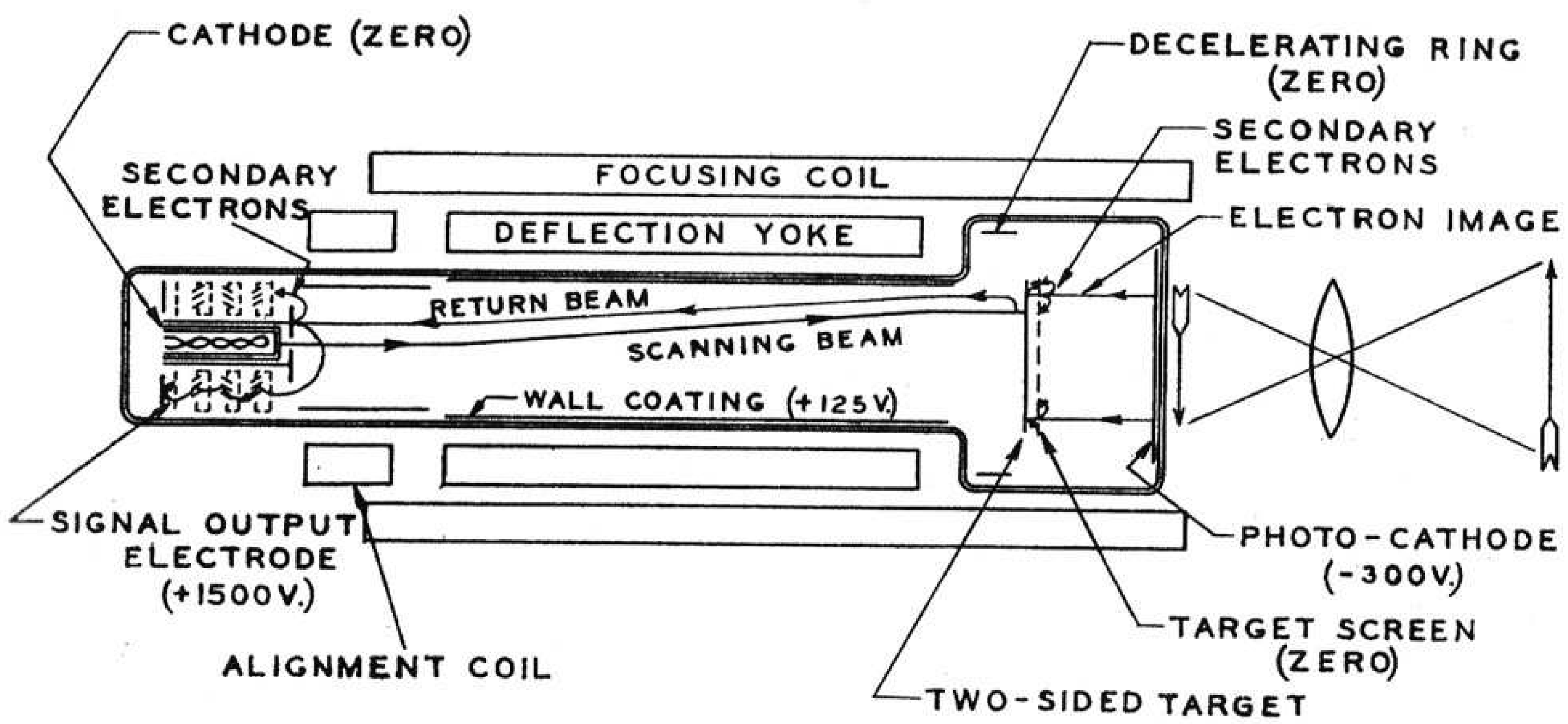

Fig. 2—Cross-sectional diagram of the image orthicon.

ducted through the glass in a frame time while lateral leakage is negligible. Excess beam electrons not deposited on the glass form a modulated return beam which is directed into a five stage multiplier. The video signal from the output of the multiplier is fed into the camera video amplifier.

Aside from reduced size, the principal ways in which the Mimo tube differs structurally from the image orthicon are:

(1) All electrodes including the image section are mounted on a single assembly with all the electrical connections brought out through a single 18-lead stem of the miniature button type.

(2) Additional fine mesh screens are used in front of the target and photocathode for the purpose of controlling the shape of the electric fields.

The results of these changes are described in the following sections along with a discussion of performance as a function of target area.

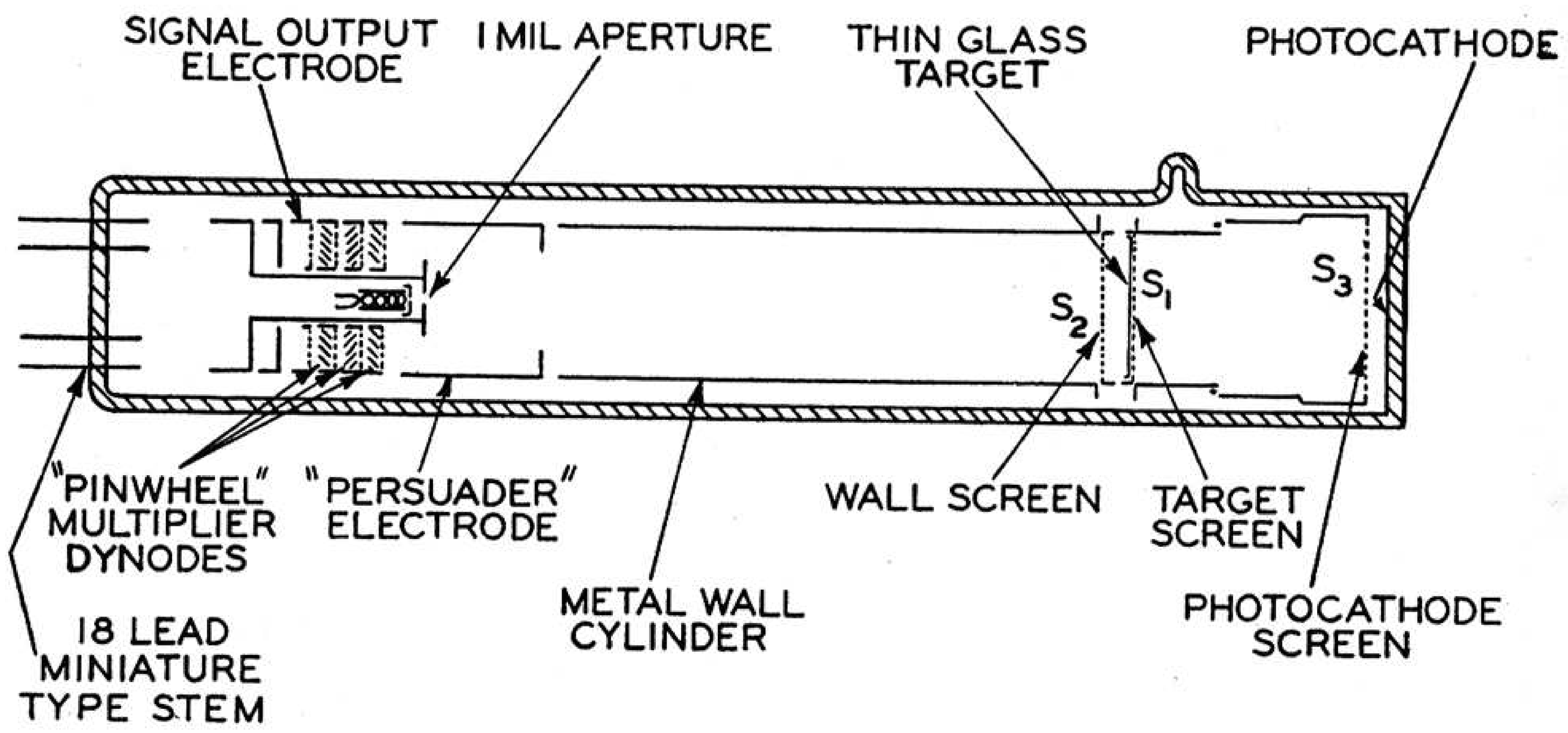

Fig. 3—Cross-sectional diagram of the Mimo tube.

Structural Details of the Mimo

A cross sectional drawing of the Mimo tube is shown in Figure 3. The overall length is 9″ (as compared to 15¼″ for the image orthicon) and the maximum diameter has been reduced from 3″ to 1½″. These dimensions allow a substantial reduction in weight of copper, and power required for the focusing and deflection coils, as well as the use of a smaller lens.

In the type of assembly used in the Mimo tube the metal wall cylinder is of thin nichrome and replaces the platinum coating used in the image orthicon. Ceramic tubing supports all electrodes (except within the gun) and the target connections are made to the stem by means of wire leads pushed through the ceramic tubing. Mandrels are

used to align the cylinders during assembly, making possible a more accurate alignment than if the target structure were mounted independently as was done in previous tubes.

A gap of 180 degrees between two ceramics is left between the target structure and the wall for convenient insertion of the glass target and wall screen just prior to sealing. A spring contact to a metal button on the inside of the glass envelope connects the photocathode to the proper lead in the stem.

A glass envelope of uniform diameter is used for the Mimo tube in order to take advantage of the single unit construction without requiring the additional sealing operation over the target. This fact, combined with the elimination of the leads at the shoulder, greatly simplifies the glass blowing operations. The molded miniature type stem which requires no basing is extremely convenient.

It was found that the performance of the multiplier was unaffected by scaling it down from 1½″ to 1″ diameter. The persuader electrode is tied electrically to the first stage instead of being brought out on a separate connection as before. The gun is made slightly smaller in diameter and the defining aperture reduced to about 1 mil.

Vibration tests showed the Mimo to be structurally quite strong. One tube was found to be operable after having been subjected to an acceleration of 25 g's.

Use of the Wall and Photocathode Screens

The availability of fine mesh screens of high transmission and uniformity have made practical the use of screens for controlling the electric fields in front of the target and photocathode. These screens, labelled S_2 and S_3 in Figure 3, are mounted directly on the wall and target structures, replacing the separate "decelerating ring" and "photocathode ring" of the image orthicon. Unlike the target screen, S_1, they are positioned far enough from a nodal plane of the electron stream that their meshes are not superimposed on the transmitted picture.

One advantage of using screens in this manner is that good focus at the edges of the picture and freedom from distortion are automatically assured without requiring separate adjustment of ring voltages. Furthermore, the screens permit high fields in front of the target and photocathode without requiring high voltages. Uniform landing of the low-velocity beam at the edges of the target is easily obtained, and the position of the deflection coil for best landing is less critical.

Another important advantage gained by the use of the wall screen is the elimination of the multiplier shading control found in the image orthicon. The screen compels the electric field in front of the target to become more nearly parallel to the magnetic field. This reduces the translational effect on the beam which is the major cause of the scanning of the first stage of the multiplier by the return beam. The consequence of this reduction in scan is that the requirement of uniform gain of the first stage is somewhat less stringent. As a result there is no need to adjust the persuader voltage for controlling uniformity of gain. The persuader electrode of the Mimo is connected internally to the first stage lead.

It should be pointed out that the screens result in some loss in signal-to-noise ratio (in some cases as much as 30 per cent). Also, the two extra screens are potential sources of spurious signal. The wall screen is the more critical of the two because the beam passes through it twice. In spite of the fact that both the scanning beam and the return beam are out of focus when passing through this screen a spurious interference pattern simulating a mesh appears under certain conditions. This pattern can be minimized by proper spacing of the wall screen and the target.

In the airborne application for which the tube was designed, the advantage of the screens in simplifying operation considerably outweighed the accompanying disadvantages.

Performance As a Function of Size

The active target area of the Mimo tube is slightly more than one quarter of that used by the image orthicon. This reduction affects performance from the standpoint of resolution, signal output and optics of the camera lens.

1. *Resolution*

Assuming that the resolution is limited electron-optically only by chromatic aberration and the stiffness of the beam at the target, it follows that a reduction in size of the tube, while keeping the voltage constant, should have no effect on the number of television lines which may be transmitted. The higher fields in the smaller tube should reduce the spot size in proportion to the change in dimensions. Actually, other less fundamental factors enter in to determine resolution — factors whose contributions are not as readily scaled down with tube size.

Loss of resolution by target leakage, for example, may arise from the volume conductivity of the glass or from the surface conductivity caused by a conducting coating of caesium on the glass. The first cause depends mainly on the resistivity and thickness of the glass and may be practically eliminated by using thinner glass in the small tube.

(Targets as thin as 0.05 to 0.1 mil were used in the Mimo tube). However, caesium leakage, when present, will deteriorate resolution to a greater extent with a target of small dimensions.

The superposition of the target screen upon the transmitted picture requires a finer mesh screen for the Mimo tube. An improvement in maximum resolution resulted when a screen of 500 meshes per linear inch was replaced by a screen of 1000 meshes per linear inch.

Cross talk in which the stray deflection fields disturb the paths of the photoelectrons in the image section might be expected to scale down proportionally with tube size. However, in the Mimo tube the deflection coil, for compactness, has been placed relatively closer to the target than in the image orthicon. This makes the cross talk a more critical problem. An effective solution is the use of iron wire wound over the deflection coil in combination with a cylindrical copper shield over the image section, but the position of the copper shield is quite critical. Alternative methods of reducing cross talk are an iron ring on the end of the deflection coil or a "bucking coil" over the image section fed by a small fraction of the horizontal deflection voltage. The cross talk from the horizontal deflection coil is more persistent than from the vertical coil. The shortened storage time of the image orthicon type of target, when the light is raised, rapidly erases the effect of "vertical" cross talk but has no effect on the "horizontal" cross talk until extremely high lights are reached.

The resolution required of the Mimo tube for the airborne television project was 250 lines at high lights, and this was easily met. (See Figure 4 and Figure 5). A number of tubes when carefully set up under experimental conditions with high light illumination showed more than 500 lines. The high limiting resolution of the scanning beam is evidenced by the fact that by under-scanning the target (to remove the video amplifier frequency band limitation) the individual wires of the 1000 mesh target screen can be resolved. This is equivalent to 2000 television lines per inch. Separate tests have shown that under ideal conditions the image section is also capable of equal resolution. The contrast ratio near the limiting resolution is, of course, very low.

The limiting resolution of the small tube is enhanced by the use of the wall and photocathode screens as well as by the use of a smaller defining aperture in the gun. However, it should be pointed out that high light resolutions approaching that of the image orthicon can be attained only if great care is taken in selection and adjustment of the tube.

2. *Signal Output*

At very low light levels, where full storage occurs, the signal output at the target is independent of tube size. This assumes that the camera lens aperture is adjusted to give the same depth of focus.

At high lights the area of the target is important in determining signal output. For a "close spaced" target (i.e. glass-screen spacing less than one picture element) the signal output varies as the target area and signal-to-noise ratio varies as the diameter. For "wide spaced" targets (i.e. glass-screen spacing wide compared to a picture element) the signal output varies more nearly as the diameter of the target and signal-to-noise ratio as the $(\text{diameter})^{\frac{1}{2}}$. The target spacing of the Mimo is of the order of two mils which is about the same as in

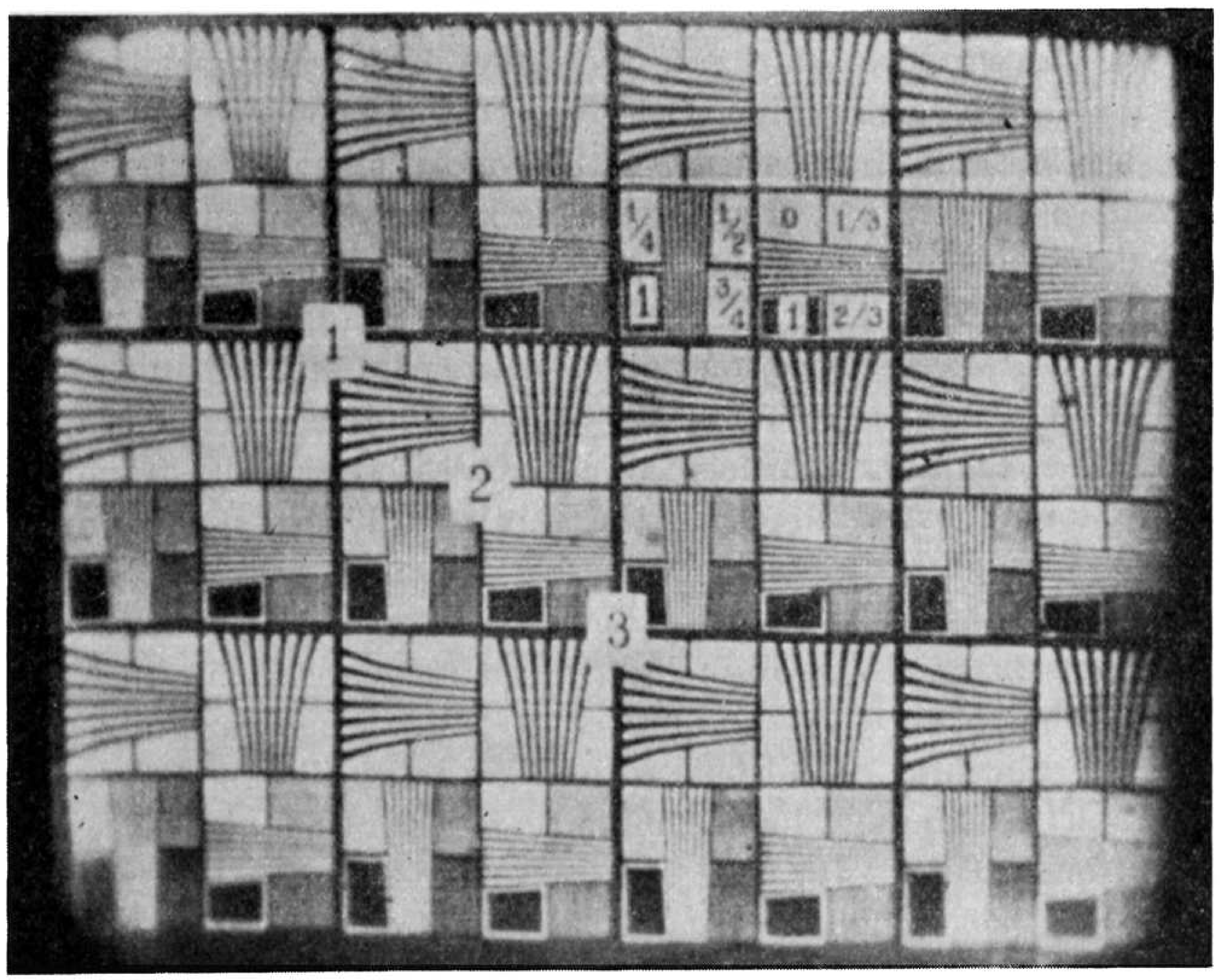

Fig. 4—Photograph of a test pattern transmitted by the Mimo tube.

the image orthicon. Because this is somewhat intermediate between "close" spacing and "wide" spacing, the drop in signal-to-noise ratio is bracketed by the above limiting cases.

Another factor influencing the variation of signal with target area at high lights is the degree of overlapping of the beam spot in adjacent lines. Some overlapping does occur in the Mimo tube (in spite of the high *limiting* resolution quoted above), and this would contribute to enhanced signal at high lights owing to the recharging of the target between successive scans.

3. *Choice of Lens*

The first consequence of the smaller photocathode of the Mimo tube is that a shorter focal length lens may be used for the same angle of view. This results in a saving in space although a faster lens is required. If, in addition, the lens diameter is also scaled proportionally, so that the numerical aperture remains unchanged, increased depth of focus is obtained at the expense of operating sensitivity.

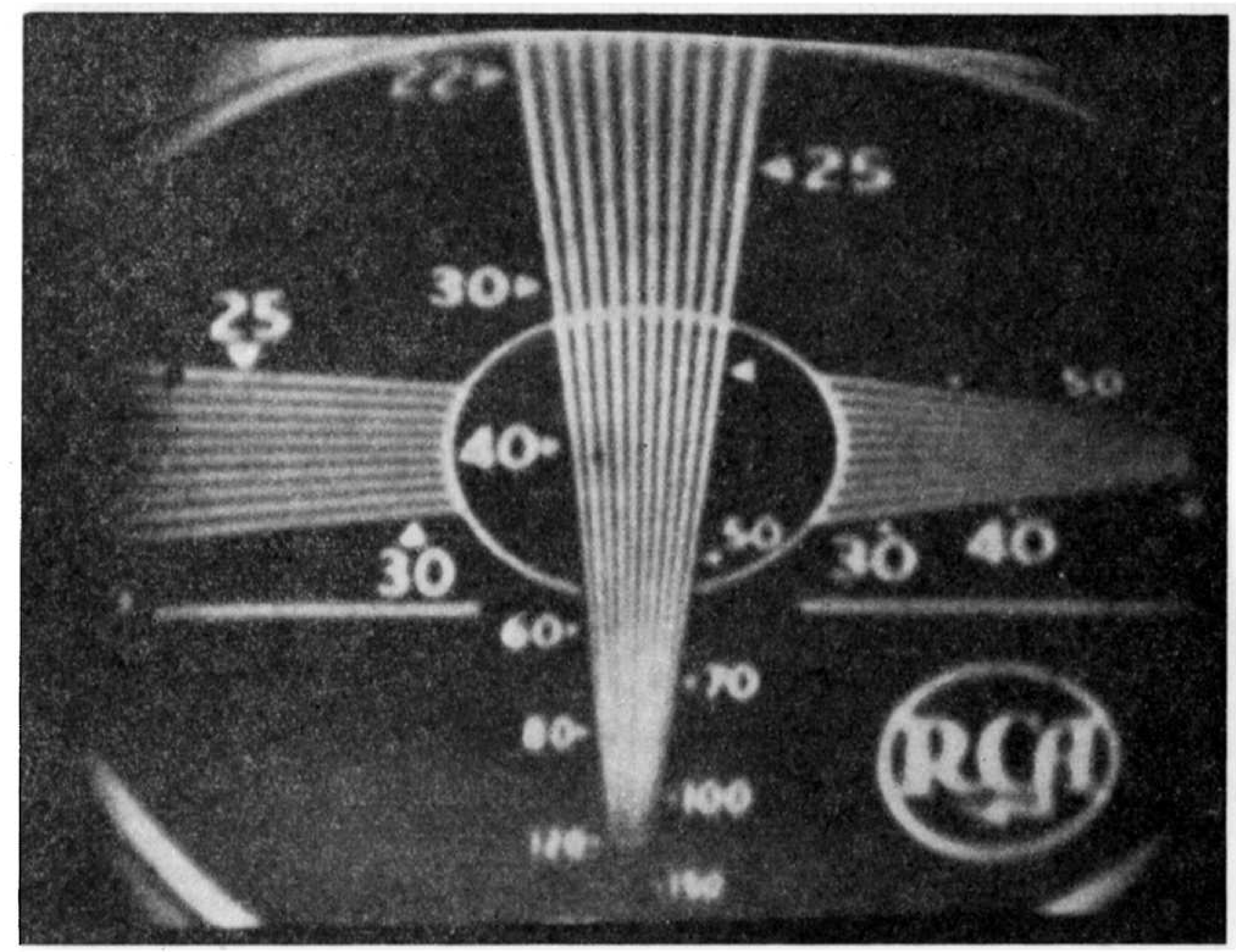

Fig. 5—Enlarged section of a test pattern transmitted by the Mimo tube. (The optical pattern was projected on the photocathode at normal size while the scanning amplitude was reduced to cover only the center portion of the target. This procedure tests the resolving power of the tube by reducing the limitations of the amplifier frequency response as well as cross talk in the image section. The numbers on the pattern should be multiplied by ten to give the resolution in television lines.)

At high light levels, in which range the signal output is substantially independent of scene brightness and in which range the Mimo was mostly used, lens speed is of no importance. Here the shorter focal length lens is an unalloyed gain in conserving space.

The size of the image projected on the photocathode of the Mimo is approximately the same as that of one frame of a 35-millimeter motion picture film. Thus a wide choice of lenses for the Mimo is at hand. An f/2.0 lens was used in the camera but light conditions in the airborne application were such that the lens was often stopped down to as small as f/22.

Conclusions

A useful television pick-up tube of reduced size has been developed for airborne television purposes. This tube retains the high sensitivity and stability under adverse lighting conditions which have characterized the image orthicon. At the same time changes in design have been incorporated which make for simplified operation of the camera. It is believed that the Mimo tube represents a first step toward the development of a television camera which approaches the miniature photographic camera in convenience and portability.

Acknowledgments

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