A Practical Television Tube for Low Light Levels

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The image orthicon, which is very widely used for the production of broadcast quality television pictures, is very sensitive and capable of operating satisfactorily down to illuminations on the scene of a few foot candles. There are a number of limitations however, fundamental to the image orthicon mode of operation, which will set the lowest light level at which it may be used. Two of these limitations are reduced by the use of Isocon read out which is employed in the tube described in this paper.

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IN order to discuss the limitations in the image orthicon the principle of operation of the image orthicon will be briefly described (Fig. 1).

Light from the scene, after passing through the lens, is imaged on to the semi-transparent photocathode. The emitted photo-electrons are accelerated and focused by electric and magnetic fields and, after penetrating the target mesh, strike the surface of the glass target causing secondary emission. As the secondary electrons have an energy above the first crossover, the surface of the target charges positively due to collection of secondaries by the target mesh which is held at a positive potential.

The positive charge image is transferred to the reverse side of the target by conduction through the target which is made of conducting glass.

A beam of electrons, produced by the electron gun, scans across the reverse side of the target by magnetic deflexion. The beam approaches the target with very low energy and is only able to land on areas which have been charged to a positive potential corresponding to the white parts of the picture. Even in these areas not all the beam lands and in the target areas corresponding to picture "blacks" none will land. The part of the beam which does not land returns almost along its original path and strikes the first dynode of the multiplier system. The output signal is obtained as the difference in multiplier output current between the black parts of the picture (maximum current) and the white parts of the picture (minimum current).

One limitation of image orthicon performance arises from the fact that the main source of noise in the tube is shot noise in the return beam. Since the beam is unmodulated for the black areas, the noise is a maximum for these parts of the picture. Thus at low light levels where the beam modulation is low gradation in the darker areas of the picture will be lost in the noise.

A further limitation in the image orthicon arises because the beam must be set at a sufficiently high level to discharge areas of the target corresponding to picture highlights. The noise associated with this level of beam effectively restricts the ability of the tube to handle a wide contrast range within the same seam—in other words its 'dynamic range' is poor.

These limitations are largely overcome by the Isocon read-out.

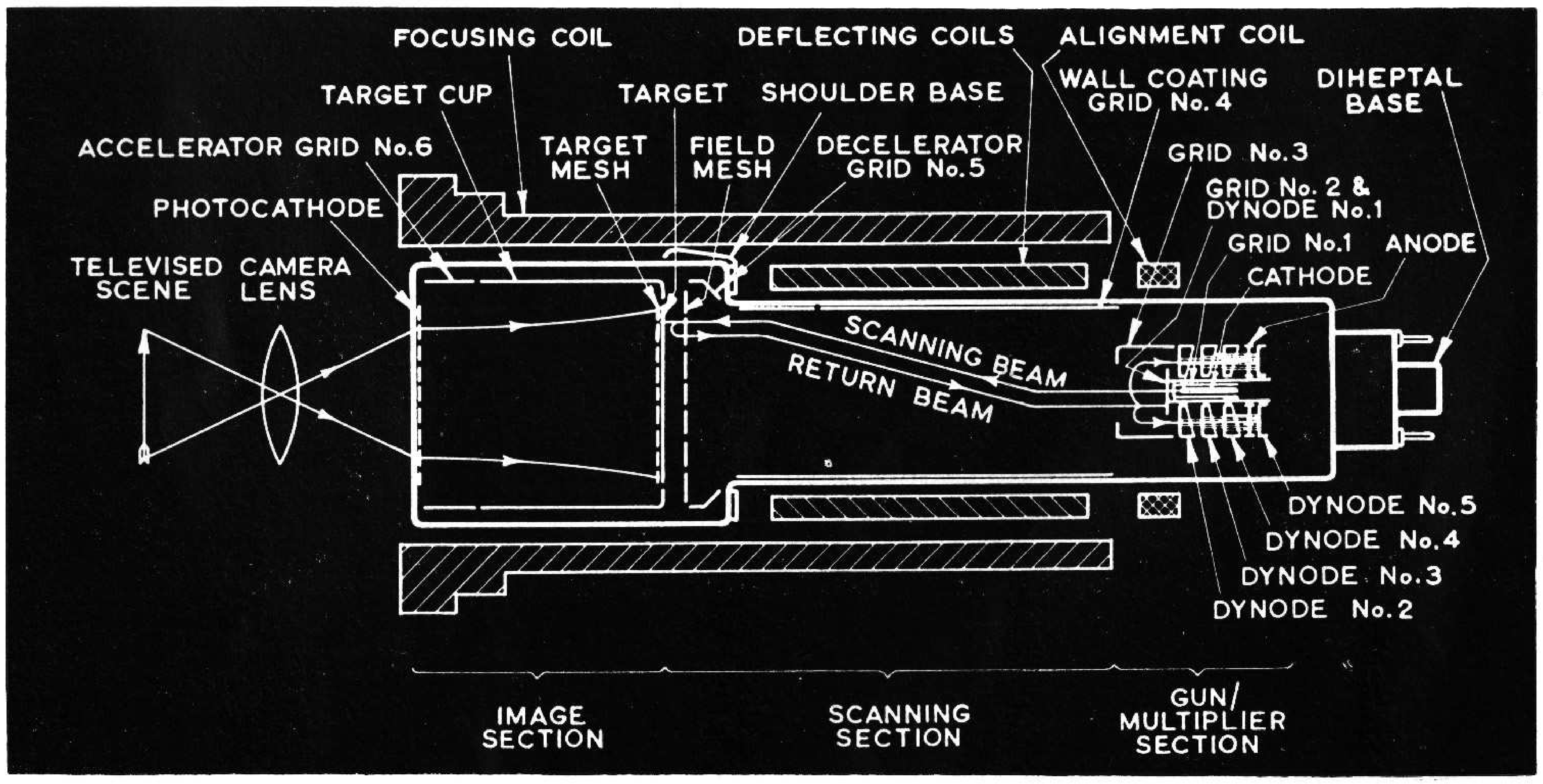
Principle of Operation of Isocon Scan

The principle of isocon scan was first investigated by Weimer[1] before 1949. Some further work was published subsequently[2,3], but it is only recently that isocon tubes have become available.

Isocon scan is based on the fact that there are actually two return beams in the image orthicon. One is a specularly reflected beam having a high shot noise content associated with the original scanning beam, while the other is a scattered beam which carries only picture information.

By discarding the first beam and using the second beam a video signal is obtained which is free of noise in the

Fig. 1. Arrangement of image orthicon



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blacks. Thus the limitation of the orthicon due to maximum noise in the blacks is overcome.

Details of Isocon Operation

In one form of isocon structure the scanning beam (Black beam, Fig. 2) is emitted from the aperture in the first dynode and, after passing through the aperture in the separator, passes between the steering plates where it receives a transverse component of velocity causing the beam as a whole to spiral in the magnetic field and approach the target at a low angle of incidence. The beam, on reaching the target, becomes split into three components.

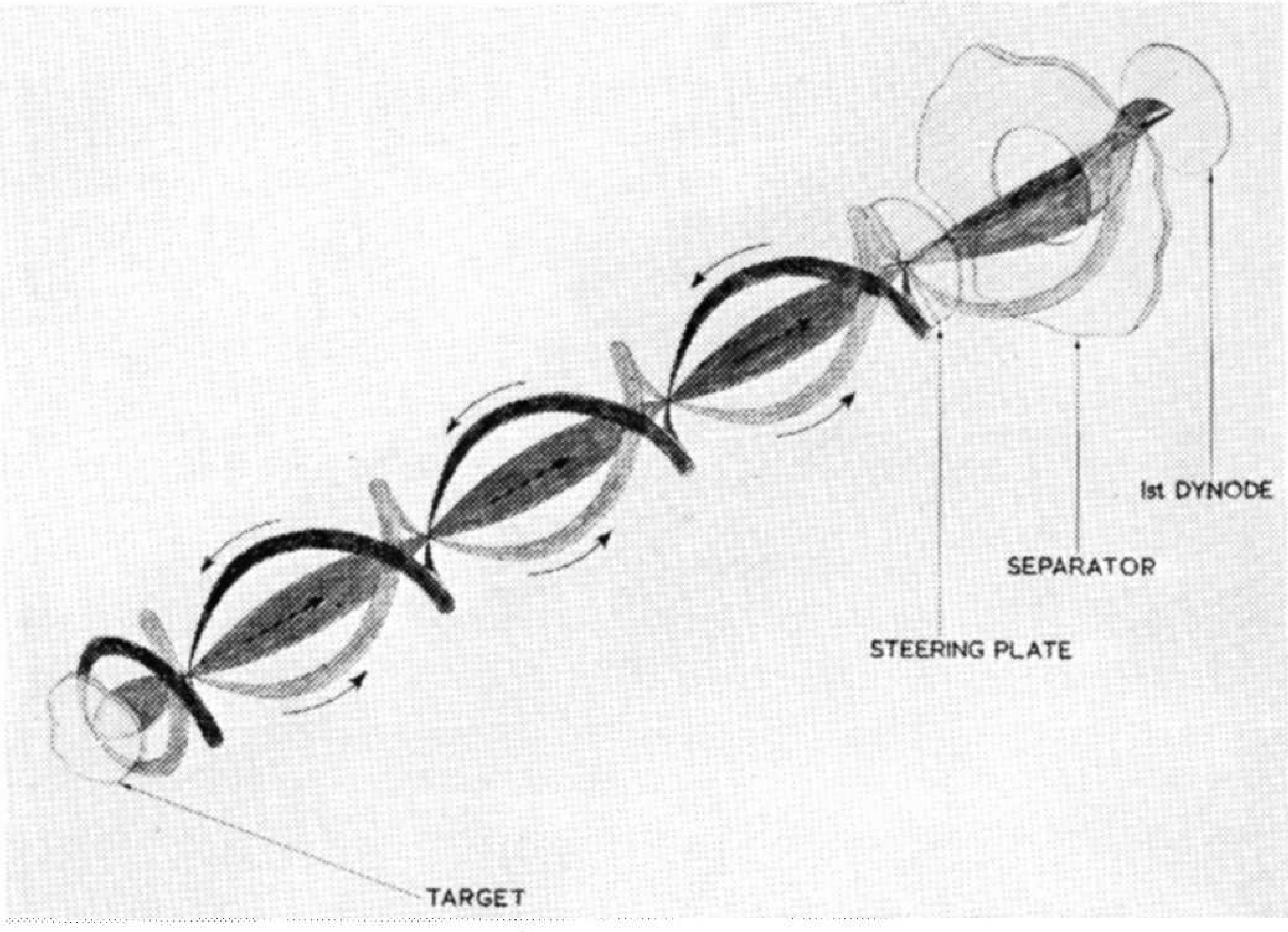

Fig. 2. Electron beams in the Isocon

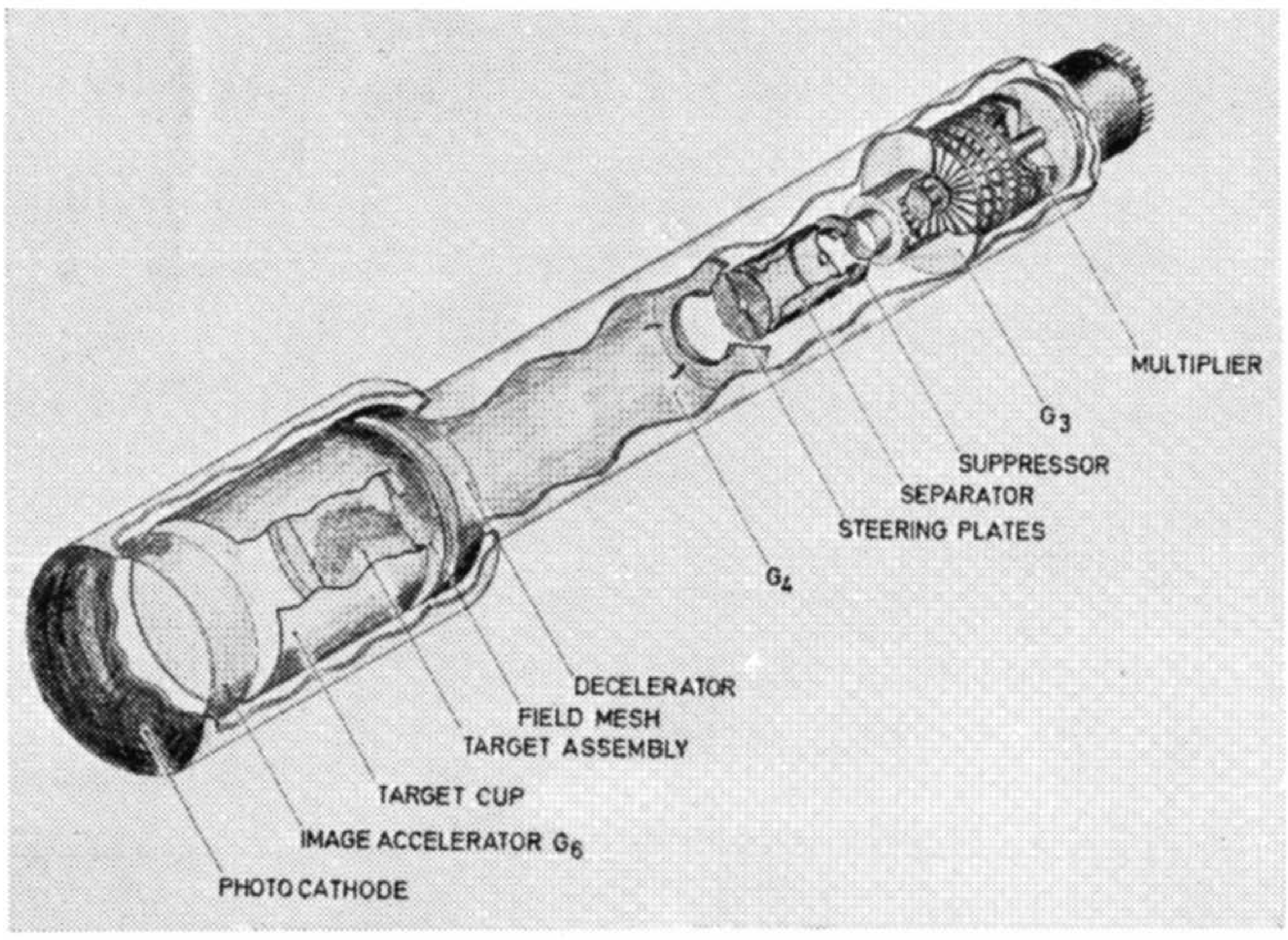

Fig. 3. Isocon cross-section

(1) The Specularly Reflected Component

Part of the beam is specularly reflected in front of the target (light grey beam).

This returns on a helix of the same pitch as the incident beam and passes between the steering plates. Here it gains further transverse velocity, increasing the diameter of the helix which then becomes sufficiently large that the beam is intercepted by the edge of the separator aperture and discarded.

(2) The Discharge Component

Some of the beam lands on the target and neutralizes the positive charge built up by the exposure of the tube to light.

(3) The Scattered Component

The positive charge on the target corresponding to the incident image, also causes part of the beam to be scattered. There are three important features of this scattered beam.

(a) Its magnitude is proportional to the positive potential on the target at the particular picture point under consideration.

(b) It is free from the noise originally present in the incident scanning beam.

(c) The helical motion in the incident scanning beam is not transferred to the scattered beam. The scattered beam returns towards the multiplier without any helical motion, and passes between the steering plates. Here a transverse component of velocity is imparted to it causing it to spiral but the radius of the helix is sufficiently small that it can still pass through the aperture in the separator and strike the first dynode. The output signal is then obtained from the anode of the multiplier.

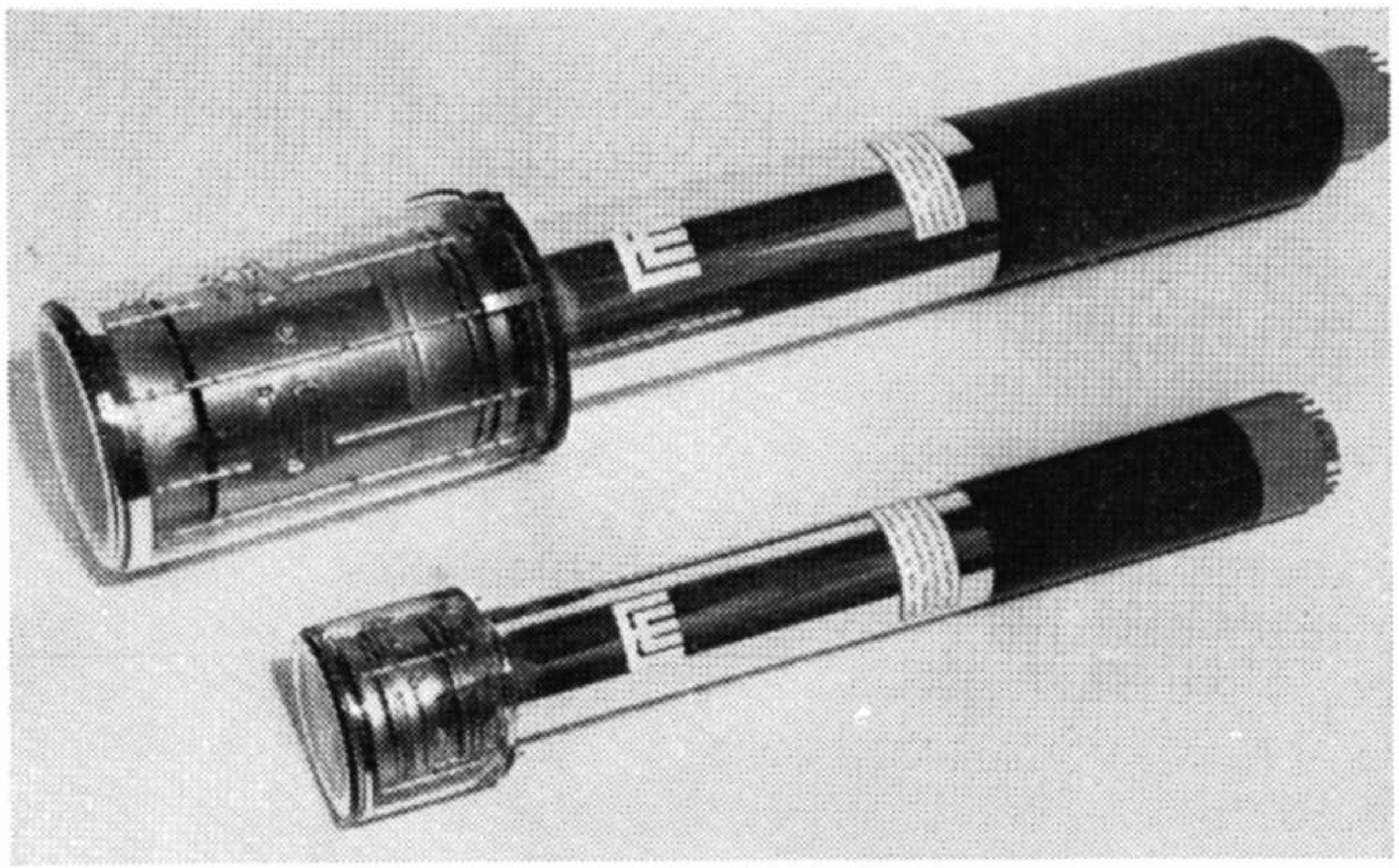

Fig. 4. The 4½in and 3in Isocon

The P.850

This tube, which was developed at E.E.V., operates on the principle of isocon scan and is shown in the cutaway diagrammatic form in Fig. 3. A photograph of a tube is shown in Fig. 4 (Back). This photograph also shows a 3in version at present under development. (P.880—Front). Both tubes incorporate the Elcon target developed by E.E.V. This target is made of electronically conducting glass which was specifically developed to overcome all the disadvantages of ionically conducting glass targets.

In the P.850 a curved faceplate is used to permit electron optical demagnification from the 3in diameter tri-alkali photocathode to the 2·4in diameter target. For use with refractive optics having a flat field, a specially computed field flattener is used. Alternatively the curved faceplate is of the correct radius of curvature to fit a commercially available mirror optical system.

The overall length of the tube is approximately 25in and the maximum diameter 4½in. The 3in version is approximately 2in longer than a standard 3in image orthicon.

PERFORMANCE

(1) *Signal to Noise Ratio*

Because the separation of the beam is not absolutely perfect, a finite signal-to-noise ratio is obtained. Expressed as the ratio of signal to the r.m.s. noise with the tube capped, the signal-to-noise ratio obtained with the beam critically set is typically:

42dB at 10^{-4}ft candles incident on the photocathode.

31dB at 10^{-5}ft candles incident on the photocathode.

The illuminant is specified at 2870°K colour temperature.

(2) *Resolution versus Light Level*

Fig. 5 shows a graph of typical limiting resolution against illumination on the photocathode.

This very good low light level performance permits the televising of scenes illuminated by moonlight or even starlight through cloud.

(3) *Dynamic Range*

The Dynamic range may be defined as the ratio:

Light level for the "knee"/light level for the threshold picture.

The threshold picture is adjudged where a black to white transition is just discernable the beam being set at the level to discharge the knee picture for both measurements.

The isocon has a dynamic range ten times better than that of an image orthicon.

The typical dynamic range for the P.850 is 2000:1 compared with approximately 200:1 for an image orthicon.

This improved dynamic range allows information to be obtained from all parts of a wide contrast scene without the necessity of adjusting the tube operating conditions.

APPLICATIONS

The improved low light capabilities of tubes employing isocon scan offers the possibility of employing three 3in tubes to produce colour pictures under adverse conditions of lighting, where colour pictures cannot at present be produced. For black and white television a single P.850 or P.880 may be used to produce good quality pictures at low light levels.

In addition to possible broadcast use, the P.850 has numerous closed circuit applications where the best possible use must be made of the limited light available.

Fig. 5. Limiting resolution against p.c. illumination

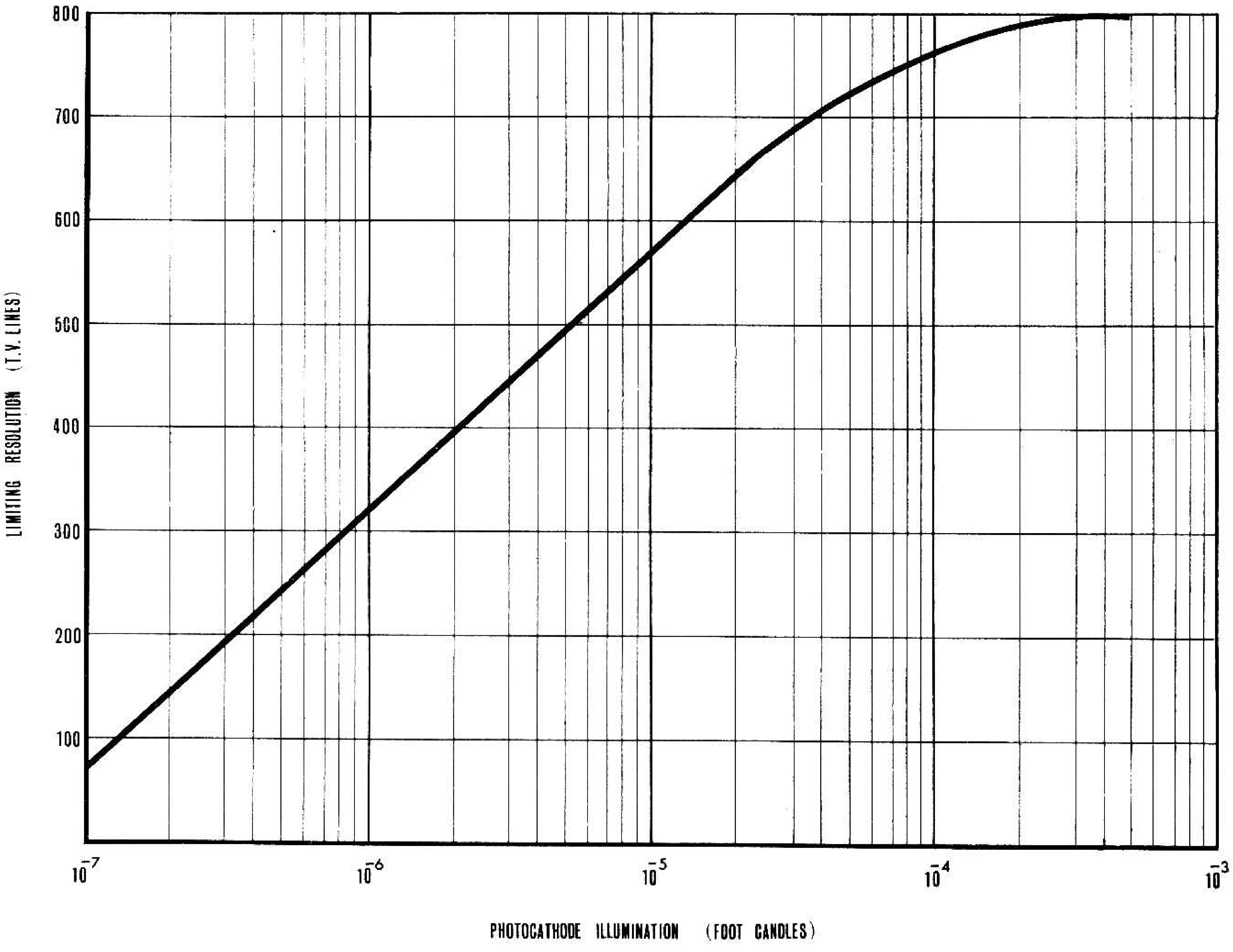

Fig. 6. Marconi Instruments' camera

It has been shown by extended trials of experimental P.850's in an X-ray image amplifier by that it is possible to reduce the X-ray dosage below that required for the image orthicons previously used in the system.

Other possible applications of the tube include astronomy, and many other scientific fields where light is limited.

Some examples of results obtained using a P.850 are shown in Figs. 7 to 14. All these pictures were produced using the low light level camera, manufactured by Marconi Instruments Ltd shown in Fig. 6, using a 4in $f/1{\cdot}4$ lens. The television standard used was 625 lines, 25 frames per second.

Fig. 7 shows a scene illuminated by the full moon, giving an incident light level on the scene of 3×10^{-2} lumens/ft^2 lens aperture $f1.4$, angle of view 40°.

Fig. 8 shows the same scene but with a neutral density filter in front of the lens, giving a simulated incident light level of 1.6×10^{-4} lumens/ft.

Fig. 9 shows a scene on a cloudless, moonless night. The incident light level on the scene was 5×10^{-4} lumens/ft^2. Lens aperture $f/1.4$.

Fig. 10 shows a star field, exposed 1/25sec lens aperture $f/1.4$, field of view 40°. 8th magnitude stars have been identified by astronomers.

Fig. 11 shows a picture of the moon taken from a P.850 display. The image from the eyepiece (magnification 180×) of an 8in reflecting telescope being projected directly on to the tube photocathode.

Fig. 12 and Fig. 13 are isocon pic-