techniques, image converters such as those constructed by A. Lallemand should ultimately be capable of extending the limit of detection 2·5 magnitudes. On the other hand, devices which store the image electrically and utilize a scanning beam to read it are limited principally by the noise in the scanning beam rather than by saturation. If the scanning beam is to record images over a range of five magnitudes, the signal-to-noise ratio will be decreased at least by a factor of ten. This loss may be avoided by the introduction of sufficient multiplication (of the order of 100) in stages preceding the scanning process.

The choice between various methods should rest entirely upon which system most closely retains the initial signal-to-noise ratio of the photocathode for threshold objects. It appears that either the converter method reviewed by Lallemand in paper no. 1 or the electron-storage method reviewed by Morton in paper no. 2 might in fact be made to approach to within $\sqrt{2}$ of this signal-to-noise ratio. The advantages to be gained, however, are so great and the cost so small, in comparison with those achievable with larger telescope apertures, that it would seem foolish not to push development along several lines simultaneously.

8. DEVELOPMENT PROGRAMME ON PHOTO-ELECTRONIC IMAGE TUBES IN THE DEPARTMENT OF INSTRUMENT TECHNOLOGY, IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY, LONDON

By J. D. McGee

Experimental work on a conventional Lallemand photographic image converter is being carried out in order to gain experience and to explore various possibilities.

An image converter is also being developed in which the electron image is formed on a fluorescent screen on the inner surface of a very thin (< 100 microns) glass window, 1 mm. × 20 mm. or smaller, capable of supporting atmospheric pressure. The photographic film is brought into contact with the outer surface of the thin glass. Thus, little fluorescent light is lost, and an efficiency comparable with that of the photographic image converter should be obtained. This is particularly designed for the registration of spectra.

Experimental work is in progress on a specialized television signal generating device. In the interest of developing a more efficient tube for astronomical purposes, we ignore the limitations and standardizations conventionally imposed on the design of commercial television tubes. In particular:

(1) The charging and discharging of the storage target can be sequential instead of simultaneous.

(2) The discharging can be done more slowly with the advantages of better signal-to-noise ratio and more efficient discharging of the integrated charges.

(3) The capacity of the electron-storage target can be increased, thereby enabling charge integration to be continued until the signals from very faint stars are large compared with the fluctuation (noise) in the background.

(4) The storage target can be made to have extremely good insulation, hence insuring no loss of image detail due to charge leakage over long periods.

The tube design suggested in March 1952 in the *Journal of the Royal Society of Arts*, no. 4869, p. 343, and later at the Manchester Symposium on Astronomical Optics, April 1955, is the basis of this work. Initially, a modified design is being tested in which a reversible storage target is mounted on pivots. After it is charged by photo-electrons incident from one direction, the target is then turned 180° and the integrated charges are discharged by a conventional scanning beam incident from the opposite direction. The storage target obviously can be made double-sided, so that one surface is being charged while the other is being discharged. It may, for example, be a metal disk with a thin film of suitable insulating material coating both surfaces, the metal disk serving as the 'signal plate'. Positive charges are built up on the surface of the insulator by secondary electron emission or possibly by bombardment-induced conductivity. With such a device the quantum efficiency should be 100 times that of a photographic plate, the number of significant photo-events which can be recorded per unit area should be at least 100 times that possible with fast photographic plates, and the uniform background can be subtracted electronically from the wanted picture in order to enhance its intelligibility.

9. JOINT COMMITTEE ON IMAGE TUBES

By J. S. Hall, *United States Naval Observatory*

In December 1953 a joint committee on image tubes was established by Dr Vannevar Bush, president of the Carnegie Institution of Washington, and funds were made available for its activities by the Carnegie Corporation of New York. The joint committee includes Merle A. Tuve (chairman) of the Carnegie Institution, L. Marton of the U.S. National Bureau of Standards, W. A. Baum of Mount Wilson and Palomar Observatories, and J. S. Hall of the U.S. Naval Observatory.

During 1954 the committee investigated the feasibility of adapting or modifying commercial image tubes for astronomical use, particularly image orthicons and vidicons. Most of this work was carried out at the National Bureau of Standards by L. Marton and E. S. Dayhoff. Except for certain limited applications involving high surface brightnesses, such as the observation of planets or the solar spectrum, it was concluded that the image orthicon in its present commercial form would require several fundamental modifications or improvements to meet the low-brightness requirements of primary interest to this committee. Two types of improvement would be essential. One of these is concerned with the electronic integration and storage of an image for a sufficiently long time without loss of definition; the second concerns the present difficulty of transferring the electronically stored image to a permanently recorded picture without serious loss of useful information. Work on electronic storage tubes is being carried out at several laboratories. Although this work will be watched with considerable interest by the committee, it was decided that a new project in this field was not justified and that the efforts and resources of the committee should be turned to a channel of more immediate promise.

There are two general methods by which the advantage of photocathodes over photographic plates can be utilized, the advantage being that which results from a 100-fold gain in quantum efficiency. In paper no. 3 these were designated as methods (*a*) and (*b*); they are represented respectively by the converter systems which Prof. Lallemand described in paper no. 1 and by the electron-storage tubes (such as the image orthicon) which Dr Morton described in paper no. 2. In principle, the two methods offer identical opportunities for an improvement over unaided photography, but in practice some of the image-converter schemes appear to have more immediate promise for low light-level applications entailing long exposures.

During the first half of 1955 the committee launched an effort to develop a particular type of image converter for commercial mass production. This device, which has been explored in the laboratory by Hiltner and Burns, is called a 'thin-film converter'. It has a very thin film stretched across the end where the fluorescent screen would otherwise be located. The photo-electron beam can pass right through this film, but gas molecules cannot; consequently, the thin film permits the electronic image to be formed outside the tube while the high-quality vacuum inside the tube is preserved. When a photographic plate is placed behind the thin film, the impinging electrons create a latent image just as in Lallemand's system.

The Farnsworth Electronics Company and the Radio Corporation of America are both co-operating with the committee in the experimental production and testing of these new