29. Newkirk, Jr. G., Bohlin, D. *Applied Optics*, **2**, 131-140, 1963.
30. Öhman, Y. *Applied Optics*, **2**, 89, 1963.
31. Öhman, Y., Rydgren, B. *Proceedings of the Los Angeles Conference*, October 30, 1962.
32. Oshurko, V. V. In *New Techniques in Astronomy*, Publ. Acad. Sc. U.S.S.R., 1963.
33. Ramsay, J. V. *Applied Optics*, **1**, 411, 1962.
34. Rozhkovsky, D. A., Dzhakusheva, K. G. *Izv. astrofiz. Inst. Ak. N. Kazakh. SSR*, **14**, 34, 1962.
35. Sabinina, Yu. A., Egorava, V. P., and others. In *New Techniques in Astronomy*, Publ. Acad. Sc. U.S.S.R., p. 28–104, 1963.
36. Strand, K. Aa. *Applied Optics*, **2**, 1, 1963.
37. Ten Bruggencate, P., Voigt, H. H. *Veröff. Univ. Sternw. Göttingen*, no. 122, 1958.
38. Tiit, V. *Bull. Stations optical Satellite Tracking*, **5**, (15), 1, 1960.
39. Vandekerkhove, E. a, *Commun. Obs. R. Belgique*, no. 207, 1962.
40. ,, b, *Commun. Obs. R. Belgique*, no. 210, 1962.
41. ,, c, *Commun. Obs. R. Belgique*, no. 211, 1962.
42. Woolley R. v. d. R. *Quart. J.R. astr. Soc.*, **3**, 249, 1962.
43. Zhurkin, N. S., and others In *New Techniques in Astronomy*, Publ. Acad. Sc. U.S.S.R., 1963.
44. Zirin, H., Newkirk, G. Jr., *Applied Optics*, **2**, 977, 1963.

REPORT TO COMMISSION 9 FROM THE WORKING GROUP ON IMAGE TUBES

This report is divided into three main sections dealing with the following different methods of photo-electronic image detection:

I. Electronographic methods.
II. Multistage image intensifiers.
III. Scanning or television type techniques.

I. *Electronography*

1. From the Paris Observatory, Lallemand and his colleagues, Duchesne *et al.*, report on progress of their work as follows.

The development and study done on the electronic camera have mostly been concerned with the reduction of noise, the conservation of the sensitivity of the photocathode for as long as possible, the increase of resolution, the linearity of the response and the improvement of the technique of use in order to facilitate and increase the reliability of the preparation of the tube.

The reduction of the noise and the increase of the life of the photocathode depend, in particular, on the quality of the vacuum obtained in the tube during its use.

We have been able to eliminate the barium getters, the use of which creates several difficulties, in particular the necessity of dismantling and thorough cleaning of the electronic lenses. By systematic study (1) of the various parameters that determine the rate of degassing of the walls, we could diminish the latter sufficiently to be able to maintain for several days—by means of activated carbon suitably disposed and cooled—a vacuum better than 10^{-7} torr. Our study has also touched on the employment of the molecular sieves. These substances have a porous structure with pores a few angstroms in diameter and for equal volumes the absorbing surface is much larger than the surface of the activated carbon. Moreover, fabricated under perfectly controlled methods, they have the advantage over the activated carbon of having a regular and reproducible structure, and consequently more uniform properties. The use of the activated carbon as an absorbing substance has enabled us during a recent visit to the Haute-Provence Observatory to make five nights of observation with a more photosensitive layer without measurable deterioration of the sensitivity. We have also continued our study of the

https://doi.org/10.1017/S0251107X00014474 Published online by Cambridge University Press

causes of parasitic electronic emission; in particular of the importance of the emission of exo-electrons of chemical origin emitted by the photocathodes. In the actual conditions of development of the electronic camera the parasitic background of the electronic plate must not exceed a density of 0·1 on G.5, with a good photocathode layer of 40–50μÅ/lumen, after four hours of exposure.

On the linearity of the reponse of the electronic camera.

We have determined the relative sensitivity of a certain number of photographic emulsions in comparison with the Ilford G.5 plate in the normal conditions of use in the electronic camera. These measurements have been done for different optical densities. We have also determined the emulsions which had a linear curve of blackening $D=f(E)$. We have shown (**2**) that the chemical treatment of the plates was of great importance in determining the shape of the curves and that only the plate G.5 had an optical density proportional to the electronic intensity when it was developed five minutes at 18°C in the developer Kodak D19b.

Study of an electrostatic immersion objective having a cylindrical symmetry.

This study, done in collaboration with Mr C. Hézard, should allow the use of flat photocathodes with a good resolution.

2. From Meudon and Pic-du-Midi Observatories, Wlérick and his colleagues report the following summary of their work:

'With the help of Professor Lallemand and the support of his laboratory the following research has been undertaken by my group during the period 1962–63:

a. Study of the distortion of the electron image of the electronic camera. Its importance in planetary and stellar photography (C. Boussuge, G. Wlérick, N. Courtois and J. Rösch, to be published).
b. Reduction of the diffused light of the electronic camera. (A. Grosse and G. Wlérick).
c. Electronic photometry. Realization of a very uniform source of light for taking into account the local variation of the sensitivity of the photocathodes.
d. Development of an electronic camera having a capacity of 25 plates (instead of the normal 12). This camera should be operational by January 1964. (G. Wlérick.)
e. Preliminary studies for a realization of a camera with magnetic focusing. (M. Bellier and P. Philippe.)
f. Development by Wlérick and J. Arsac of a method for analysis of the electronic records: correction of the records for various causes of spreading by using the method of Van Cittert in a form adapted for calculation with an electronic computer. The astronomical applications of this method have been made in collaboration with M. Bellier, M. F. Dupré and J. Rösch.'

3. At the Lick Observatory, Walker has continued observations with the Lallemand electronic camera at the coudé focus of the 120-inch reflector in the manner already described (**3, 4, 5**).

By careful preparation, and after repeated use of the camera, operation for two nights with little deterioration of photocathode sensitivity was achieved. It then became clear that the background noise from the cathode decreased appreciably during the first 24 hours after release of the cathode from its ampoule. Although the photocathode sensitivity may also decrease during this time, the signal-to-noise ratio improves. Also two nights of satisfactory operation, that is the second and third after the exposure of the photocathode, have been found practicable. Walker attributes this initial increase in background to caesium vapour, released when the photocathode is first exposed, but gradually scavenged by chemical action with a corresponding improvement of background.

Further careful comparisons of speed of the electronic camera using Ilford G.5 emulsion

https://doi.org/10.1017/S0251107X00014474 Published online by Cambridge University Press

with direct photography on baked Eastman Kodak IIa-o and 103a-o have been carried out by Walker. He arrives at the conclusion that the speed gain of the electronic camera for short exposures of the order of 1 or 2 seconds is about the same for the two emulsions and is 8 to 12 times, depending on the photocathode sensitivity. For longer exposures of 10 minutes the gain rises only a little for baked IIa-o to about 15 times, but to a factor of about 40 for 103a-o. This is considered to be due to the much lower reciprocity failure of baked IIa-o as compared with 103a-o. These results are for light of wavelengths in the region of 4000 Å.

Walker points out that because photographic plates can be used with much more efficient optical systems than the present types of image tube, the difference in speed can be almost entirely compensated. Hence, improvements in image tube design, to allow their use with more efficient optical systems, need urgent consideration.

Walker, with L. H. Aller, has recently used the Lallemand electronic camera to obtain spectrophotometric plates of faint planetary nebulae. Advantage is taken of the linear response of the electronic system to the intensity of the incident light and calibration is obtained from observations of a very hot star of known energy distribution. The results have been very satisfactory. It has been possible even with the present mounting of the tube to record and derive intensities for much fainter lines than had hitherto been possible by conventional means.

4. Also from the Lick Observatory, Kron reports on the progress of his work with his colleagues, I. I. Papiashvili and J. Breckinridge, on the Lick-Stromlo image tube as follows:

'A successful model of the tube, a modification of the Lallemand type of tube, was constructed at the Mount Stromlo Observatory in 1961 (**6, 7**). This tube is now operational, and during the last year it has taken more than 100 plates in the laboratory and on the telescope. Each plate has six exposures; the plate is directly exposed to the photo-electrons inside the vacuum of the tube, and plates can be exchanged without sacrifice of the photocathode.

During the past eight months the tube background has been reduced very much, to the point where exposures of about two hours can be made. Since this tube minifies by a factor of between 2 and 2·5, this is equivalent to exposure times of more than eight hours for tubes of scale 1:1. The background was lowered mainly by reduction of the operating gas pressure within the tube, and by control of the plates where caesium deposits within the tube during the formation of the photocathode.

Use of this tube on the coudé spectrograph at Mount Wilson and on the Carnegie Astrograph at Mount Hamilton indicates that the gain over unaided photography in the blue spectral region is about equal to the sensitivity of the photocathode in microamperes per lumen. The conditions of operation are for an unoxidised Cs-Sb cathode, fresh Ilford G.5 emulsion, 30 kV potential on the tube.

During its life, the photocathode slowly becomes relatively more blue sensitive. We find half lives for our cathodes at present, as determined by extrapolation from operating cycles of the order of two to three months, of about five to six months for the visual and red sensitivity, and twice this for the blue sensitivity. When the photocathode is judged to be too inefficient for use, it must be replaced. This process takes about four days, and only a few seals must be replaced in the tube. All other components can be used over.

We are now working to get into operation a new tube. This tube is in principle like the old one, but many small changes have been made to increase its operating efficiency (mainly the speed of re-cycling from plate-to-plate) and its reliability. The old tube gave about 90 per cent reliability; we hope that the new one may approach 100 per cent rather closely.'

5. Work on electronographic electron image recording by a method already described (**8**) has been continued by Hiltner and his colleagues at the Yerkes Observatory who report as follows:

https://doi.org/10.1017/S0251107X00014474 Published online by Cambridge University Press

'Experimentation has been continued with electronography during the reporting period. This electronographic system is one where the photocathode is preserved during the insertion of emulsions for exposure and their removal for development. This is accomplished through a vacuum lock. The vacuum system is a cryogenic one. The refrigerant is liquid hydrogen shielded with liquid nitrogen. It has been found that the pumping speed is sufficiently great that the 1000 Å aluminium oxide foil that was used to separate the emulsion from the photocathode chamber is no longer needed. Half lives of over two weeks are obtained without a foil and without refrigeration of emulsions. The removal of the foil has increased the resolution from about 40 line pairs per mm to a value in excess of the light optics now presently used.

The system is fully operational except for creepage of the image during exposure. There are two sources for this creepage: (*a*) The Earth's magnetic field; (*b*) Electrostatic charges on insulators within the tube. The magnetic shielding must be *extraordinarily good* when the image tube is placed at the moveable end of a telescope. The removal of the latter cause may be accomplished by the redesign by the Rauland Corporation of the focusing electrode.'

6. At Imperial College, London University, work has continued by McGee and his colleagues A. Khogali, A. Ganson and M. Jamini, on the development and investigation of the Lenard window electronographic image tube.

As already reported (**9, 10**), in this tube the electron image is accelerated to about 40 keV and projected through a thin mica window about 4μ thick and 5mm $\times$ 30mm in area. The electrons record on a nuclear emulsion—generally Ilford's G.5—which is pressed into intimate contact with the mica window.

Work on the following tube features has been carried out.

a. Reduction in thickness (to 4μ) of the mica window and improvement of the technique of sealing it to the tube.

b. Improvement of ultimate vacuum to improve dark current and hence increase practicable exposure time.

c. Improvement of electrode structure to ensure the tube stands 40 kV without electrical breakdown.

d. Cathode activation procedure to achieve good sensitivity without escape of caesium into the working part of the tube which enhances spurious background.

e. Investigation of slow image drift and design of electrode structure to reduce it to an acceptable amount.

f. Comparison of different types of electronographic emulsion. To date Ilford G.5 appears to be the best compromise between speed and grain size.

g. Development of a technique for coating G.5 emulsion onto Melinex film of 25μ to 50μ thickness which could be pressed into contact with the mica window safely. This eliminates the unsatisfactory process of using emulsion stripped from glass plates which was very subject to distortion in processing. The Melinex provides a very stable base throughout the whole exposure and development process.

h. Improvement in emulsion handling technique has reduced the fog background to a very low level ($D \ngtr 0{\cdot}01$) so that the efficiency of recording very faint features is improved.

i. Careful measurement of limiting resolution with well stabilized high voltage and focus current supply units gave values of up to 80 lp/mm.

j. Comparison of the speeds of the tube using G.5 emulsion with baked IIa-o plates using white light gave gains in speed of up to $\sim$ 10 times. The reciprocity characteristics of IIa-o were also measured and the relationship of density of the electron image on G.5 with electron or light intensity, with tube voltage, and with different development methods was also investigated.

k. The characteristics of the electron transmission through the mica windows under working

https://doi.org/10.1017/S0251107X00014474 Published online by Cambridge University Press

conditions was investigated by two methods. First by direct measurement of the percentage and energy distribution of the electrons transmitted through a 4μ thick mica sheet and secondly by counting of the individual electron tracks on a very lightly exposed G.5 emulsion and comparing this with the measured number of electrons leaving the photocathode. Both methods agree in giving about 70 per cent of the photo-electrons as being effective in producing a record on the emulsion.

7. By the kind invitation of the Carnegie Tube Committee of Washington (Chairman Dr M. A. Tuve) two series of tests were carried out in collaboration with Baum of the Mount Wilson and Palomar Observatories in the late Summer of 1962 at the Flagstaff Observatory, Arizona (by kind invitation of the Director, Dr John Hall) and in the Spring of 1963 at Mount Wilson (through the hospitality of Dr I. Bowen).

At Flagstaff a permanent magnet array for focusing the tubes was constructed which gave excellent results. Besides requiring no power unit they gave excellent stability, very good uniformity, and of course no heating due to electric current. Tubes brought from McGee's laboratory gave as good results under test as had been achieved in the laboratory. Preliminary tests at the coudé spectrograph of the 100-inch telescope at Mount Wilson were unsatisfactory partly because of failure of tubes and partly due to local steel structures distorting the magnetic focus field.

These tests were continued at Mount Wilson in the Spring of 1963 with improved tubes and better magnetic shielding of the focusing field. Careful comparisons were made between 'speed' and 'information rate' of the image tubes using blue light with G.5 emulsion and baked IIa-o emulsion. In these tests Baum and McGee were joined at various times by O. Wilson, A. J. Deutsch and H. Babcock.

The speed of the image tube with G.5 emulsion relative to baked IIa-o for blue light (3800 to 4800Å) passed through a minimum of about three at a density of $\sim$0·5 and increased for both lower and higher densities, as is to be expected from the linear response of the electronographic and the non-linear response of the photographic emulsion.

Because of rather better image definition and finer grain of the electronographic image, the 'information rate' for this process was about seven times that for direct photography at its minimum and rose at higher and lower densities to about 20 and 30 times respectively. These measurements apply to a tube with a cathode sensitivity of $30\,\mu$Å/lumen and any increase in sensitivity in the blue region of the spectrum will result in a proportionate increase in the relative speeds. Also for longer wavelength light the gain of the tube over photography would increase appreciably.

After these laboratory tests, an extensive series of tests was carried out with the tube mounted at the focus of the 114-inch coudé spectrograph of the 100-inch telescope at Mount Wilson Observatory. The magnetic screening designed by Baum proved satisfactory and no ill-effects were found from rotation of the dome, etc. Some image drift was found after first switching on the high voltage, but after an hour or so this stabilized and no ill-effects due to it could be observed subsequently. However, a small residual effect probably remains and, as noted above, the main effect has been greatly reduced by subsequent investigations in McGee's London laboratories.

Over 250 exposures were made on arc spectra test patterns, photometric calibrations, star and daylight sky spectra, without damage to or difficulty with the tubes.

Exposure times up to five hours were achieved with tube background that was still low.

II. *Image Intensifier Tubes* (11)

Much work has been carried out in both the development and evaluation of tubes of this type

https://doi.org/10.1017/S0251107X00014474 Published online by Cambridge University Press

for astronomical purposes. Two versions are of interest: first the Transmission Secondary Emission (T.S.E.) tube and second, the Cascade Intensifier tube.

Transmission Secondary Emission Tubes

These are now in commercial production by the 20th Century Electronics Ltd. and English Electric Valve Co. in England and the Westinghouse Corporation in the U.S.A.

The performance of tubes available commercially is now approximately as follows: resolution >30 line pairs/mm (one case of 60 line pairs/mm has been quoted by Livingston for an English Electric Valve Co. tube); gain $>10^5$ for blue light; dark count of scintillations 10 to 100 cm^{-2} sec^{-1}; effective diameter of dynodes $\sim$ 25 to 30mm.

The main defect in the performance of these tubes is the bad statistics of electron multiplication. In many cases, less than 50 per cent of all primary photo-electrons produce an output signal and the intensity of output from those that do varies over a very wide range, possibly 100 to 1. Dunham (**12**) and Sephton, working at Imperial College, measured these effects and several observers including those just mentioned, Baum and McGee at Lowell Observatory, Flagstaff, Livingston at Kitt Peak, have found that the result of these bad statistics is to give a picture of such poor signal/noise ratio that the information gain, as distinct from speed of blackening, is small, if anything at all, when compared with direct photography.

Two methods for overcoming the effect of this unfavourable characteristic have been suggested. The first is to photograph the image on a moving film and subsequently to count the records of individual scintillations. This eliminates the adverse effect of the spread of brightness of individual scintillations. It is still under trial by Livingston and his colleagues.

The second possibility also being followed by Livingston is to use a television camera image orthicon to view the image on the output phosphor screen. This, it is hoped, will act as a temporary information storage buffer. The scintillation information is then read out sequentially and integrated by a digital system.

In Blackwell's department of Astrophysics at Oxford University Observatory, a beginning has been made in the use and evaluation of image tubes. M. F. Ingham reports that J. E. Beckman has made preliminary investigations of the resolving power, gain and spectral response of a tube supplied by McGee's department at Imperial College with encouraging results. A more extensive program of testing an English Electric tube of type P829D is beginning with a view to its early astronomical application.

Cascade Image Intensifier

The main practical problem in making this type of tube is to make and process the cascade screen. This requires a very fine grain uniform phosphor screen to be formed on one surface of a very thin sheet of mica, the other side of which is coated with an efficient transparent photocathode. One or more of these screens must be mounted in the tube and processed along with the primary input photocathode and the output phosphor, without damage to the phosphors and so that high accelerating voltage can be applied to the tube to give adequate gain without undue spurious background.

Work on development and testing of tubes of this type has been continued at the RCA and ITT under the auspices of the Carnegie Image Tube Committee. The astronomical evaluation is carried out by Kent Ford, who reports as follows:

The Carnegie Image Tube Committee, with financial support of the National Science Foundation, has tested and evaluated several types of experimental tubes made for them by ITT Laboratories and Radio Corporation of America. It is hoped that when the development of these tubes is completed they will provide a substantial gain over unaided photographic techniques and that they can be made available in some quantity for routine use in astronomical applications.

At both ITT and RCA much effort has been directed towards magnetically focused, two-stage cascaded tubes (one multiplying sandwich of the phosphor-mica-photocathode variety) with 40 mm fields. The experimental tubes produced thus far have resolutions varying from 25 to 50 line pairs/mm depending primarily on the quality of the phosphor screens. The tubes made by ITT for the Carnegie Committee have S11 photocathodes and P11 phosphors. The main difficulties have been in reducing spurious emission to a sufficiently low level to permit long exposures and in forming good photosurfaces. The RCA tubes have S20 (multi-alkali) photosurfaces and either P20 or P11 phosphors. The first tubes with P20 phosphors had good cathodes, moderate background at room temperature, but resolution of only 25 line pairs/mm. The tubes produced more recently have greatly improved resolution (40 to 50 lp/mm at the phosphor screen), but have had either poor cathodes or excessively high background.

RCA has also under development a three-stage cascaded tube (two multiplying sandwiches). Two of these have been tested briefly by the Carnegie Committee in the laboratory, but neither had the desired performance for astronomical applications.

A two-stage cascaded tube having a 85-mm diameter field has been developed by RCA. This tube has S20 photosurfaces and resolution at the phosphor screen of about 40 line pairs/mm. The principal difficulty is in adequately imaging the screen on a photographic plate.

Several ITT mica-window tubes having S1 photocathodes have been used at Lowell Observatory by Fredrick for infra-red spectroscopic observations. These tubes have S11 phosphors on windows 8μ thick. Resolution in a contact exposure is about 25 lp/mm. The tubes are cooled with dry ice but exposures are limited by spurious emission to ten or twenty minutes.

Experimental mica-window tubes with S20 photocathodes have been tested at Lowell Observatory by Ford. These have P11 phosphors on windows 5 to 8μ thick and resolution of 25 lp/mm in a contact exposure. Exposures of more than an hour could be made with the tube uncooled and the gain in exposure time was ten.'

In McGee's laboratory at Imperial College with C. E. Catchpole, M. Aslam and R. W. Airey, and part-time collaboration from Baum and Bradley, a three-stage cascade tube is being developed. The performance figures reached are: gain $\sim 10^5$ for blue light; resolution 20 to 25 line pairs/mm; effective field diameter 38 mm; bright scintillations about 1 cm^{-2} sec^{-1}; background: low at 12 kV per stage.

Much effort has been directed towards developing a design of tube which can be processed without caesium vapour reaching and depositing on the electrodes and surfaces of the tube that must be at a high negative potential during operation. This technique now works well and besides keeping the spurious background due to field emission of electrons at a low level it has also eliminated almost completely the bright scintillations believed to be due to caesium ions reaching the primary photocathode.

At present our efforts are directed towards making better phosphor screens to give minimum granularity and maximum resolution with high electron gain. Also improved photo-cathodes are required and it is planned to incorporate S.20 cathodes in the near future to improve efficiency and range of wavelengths covered.

Preliminary tests of these tubes show that the reproduced image has a much better signal/noise ratio for about the same gain than that from the T.S.E. tube. It appears that 70 to 80 per cent of the primary photoelectrons are effective in producing a record at the output, and there is a much smaller spread in the light gain for individual electrons. This type of tube appears to be the more likely to realize the theoretical gain over direct photography to be expected from the difference in quantum efficiency.

A similar cascade tube but with four stages has been developed by E.M.I. Ltd., Hayes, Middx., England. This gives a gain of $\sim 10^6$, resolution ~ 15 lp/mm, an S.20 cathode is used and few bright scintillations appear, but rather poor background. Results of detailed evaluation tests are not available.

III. *Scanning or Television Type Techniques*

In this method the primary photo-electrons released by the light image are used to build up an electric charge image on a charge storage target which is then scanned by an electron beam to discharge the stored charges and produce a television picture signal. This is then used to reconstitute the original image.

In some cases commercial type tubes are used in special operating regimes and in others special tubes are being developed for the purpose.

1. In the first category is the work of Livingston and his colleagues, C. R. Lynds and D. Trumbo, at Kitt Peak National Observatory.

In their laboratory the storage and resolution properties of commercially available image orthicons have been studied. As regard to storage, or target leakage, great variation is found. Tubes with S.20 (multi-alkali) photocathodes generally have better storage properties than those of the S.11 type. Selected tubes with oxide targets, when cooled to $-20°C$, exhibit a storage time constant of over an hour. Background due to dark current is not detectable for exposures of this duration.

If, in addition to storage, the image orthicon is selected for good internal beam alignment, they find the tube has a resolution capability which is a function of operating position on its light transfer characteristic. For exposure below the knee (i.e. on the linear portion), the resolution is 'noise limited' to about 15 lp/mm. If exposure is adjusted to reach the knee, resolution is set by inter-element capacitative coupling on the target, an effect which reduces contrast and limits resolution to about 25 lp/mm. For exposure above the knee, redistributed secondary electrons cause an increase of contrast and the resolution limit, probably set by the scanning section, is about 60 lp/mm. Details of the means by which this high resolution may be realized in practice have been given (**13**).

The image orthicon has been tested at the telescope for both direct and spectroscopic observations. The response of the tube to the stellar image is quite unlike that of the photographic emulsion. Phenomena peculiar to the image orthicon, such as the redistribution of electrons (image section), interelement capacitive coupling (target) and beam bending (scanning section), combine to give a sensitive indication of stellar magnitude and enhance the resolution (**14**).

Results of attempts to employ the tube for low dispersion spectroscopy have, however, been very disappointing. The excellent resolution and storage properties found in the laboratory did not hold up on the spectrograph. It was not possible to derive reliable, quantitative information from the transduced spectra. Initially we attributed the difficulty to the low latitude of response and methods for improving the latitude by 'beam feedback' and 'target feedback' were tried (**15**). But now we feel that the interdependence of the recorded picture elements is of greater importance and seriously limits this type of tube for astronomical spectroscopy.

2. From Dearborn Observatory, Evanston, Ill., Hynek and his colleagues, Powers and Barton, are also investigating the use of commercial television camera tubes. They report as follows:

Work with the image orthicon and its applications to astronomical problems (**16**) has continued at both the Dearborn Observatory in Evanston, Illinois, and at its field station at Organ Mountain, New Mexico. Investigations include the tracking of asteroids, the photometry of open clusters, exploration of the feasibility of using the image orthicon in a search technique for supernovae, and cooperation with the U.S. Air Force in the development of a surveillance system which involves, essentially, mapping the entire sky nightly. Such a venture obviously has great astronomical potential and means are now being investigated for utilizing the observations which can be obtained from this system.

Recent developments of interest include the discovery of a mode of operating a field mesh image orthicon tube which permits continuous moderate resolution read-out at sensitivities comparable to or better than in the normal mode of operation of this tube. The non-destructive aspect of this mode of operation should make searches for slowly moving objects much easier than when the tube is used in the intermittent read-out mode.

There is being designed at the Dearborn Observatory a non-scanning integrating image intensifier tube which employs the principle of the Foucault knife-edge test to examine an electron mirror, which is the target of an image tube. Feasibility of producing a prototype model of this tube is now under consideration.

3. In the Westinghouse Research Laboratories, Pittsburgh, Pa., Anderson and his colleagues are continuing the development of the Uvicon tube, which is a television camera tube primarily intended for detection of ultraviolet images in an orbiting astronomical observatory.

The basic design has already been described (**17**), but improvements are expected from the use of a storage target, employing transmission secondary emission instead of bombardment induced conductivity as originally planned.

4. At Imperial College, McGee, Twiddy and Mende continue work on the specially designed charge-integrating signal-generating tube for detection of very faint images, or for the detection of images suffused by a bright sky glow.

Excellent charge integration and retention for a day or so without loss of resolution has been achieved. Slow scan read-out is used to give optimum signal-to-noise ratio in a narrow frequency band amplifier, more complete discharge of the high capacity target in one scan and better electron beam focus, and hence image definition.

The main limitation at present is the rather poor image definition achieved in the read-out operation.

J. D. MCGEE
Chairman of the Working Group on Image Tubes

BIBLIOGRAPHY

Note: *Advances in Electronics and Electron Physics*, Vol. XVI, Academic Press, New York and London, is referred to as: *A. in E.* Vol. XVI.

1. Duchesne, M. *C. R. Acad. Sci. Paris*, **253**, 417, 1961.
2. Duchesne, M., Meallet, M. *C. R. Acad. Sci. Paris*, **254**, 1400, 1962.
3. Lallemand, A., Duchesne, M., Walker, M. F. *Publ. astr. Soc. Pacif.*, **72**, 268, 1960.
4. Walker, M. F. *A. in E.* Vol. XVI, 341, 1962.
5. ,, *Publ. astr. Soc. Pacif.*, **74**, 44, 1962.
6. Kron, G. E. *A. in E.* Vol. XVI, 25, 1962.
7. Kron, G. E., Papiashvili, I. I. *Publ. astr. Soc. Pacif.*, **74**, 404, 1962.
8. Hiltner, W. A., Niklas, W. F. *A. in E.* Vol. XVI, 37, 1962.
9. McGee, J. D., Wheeler, B. E. *J. Photographic Science*, **9**, 106, 1961.
10. ,, ,, *A. in E.* Vol. XVI, 47, 1962.
11. McGee, J. D. *Reports on Progress in Physics*, Vol. XXIV, p. 167, 1961.
12. Dunham, T. Jr. *Astr. J.*, **67**, 575, 1962.
13. Livingston, W. C. *J. Soc. Motion Pict. Tel. Engrs.* (in press).
14. ,, *A. in E.* Vol. XVI, 431, 1962.
15. ,, Image Intensifier Symposium, Fort Belvoir, Oct. 1961. NASA SP-2.
16. Hynek, J. A., Barton, G., Aitkens, R., Powers, W. *A. in E.* Vol. XVI, 409, 1962.
17. Schneeberger, R. J., Skorinko, G., Doughty, D. D., Feibelman, W. A. *A. in E.* Vol. XVI, 235, 1962.