cinematography. A purely mirror combination $f/20$ for radiometric observations is also available (*Pulkovo Bull.* **159**, 145, 1958). The entrance and relative aperture are selected in a manner to reduce (as far as possible) atmospheric turbulence effects and to use in planet cinematography the ordinary Agfa JSS film with short exposures.

35. V. B. Sukhov and Ju. P. Platonov (*Pulkovo Bull.* **161**, 52, 1958) gave a description of the photo-electric arrangement of the Pulkovo time service with alternating current power supply.

36. P. P. Bozhko studied in detail the Repsold meridian circle of the Nikolaiev Observatory.

PROPOSALS

Rösch points out that Commission 9, though called the Commission on Astronomical Instruments, has always dealt with both instruments and techniques. He suggests that the name of Commission 9 be modified to include the mention of techniques, thus bringing the name of the Commission into closer agreement with its function.

There is now a considerable number of coudé spectrographs in operation throughout the world. Generally, few details of these instruments have been published. Dunham suggests that an informal meeting of persons skilled in the design and use of these instruments might be timely, and might serve a useful purpose. Possibly a portion of the business session of Commission 9 in Berkeley could well be devoted to such a discussion, which, Dunham feels, should be informal and spontaneous, and not circumscribed by the preparation of papers.

G. E. KRON
President of the Commission

9*a*. SOUS-COMMISSION DES CONVERTISSEURS D'IMAGES

PRÉSIDENT: Dr W. A. Baum, Mount Wilson and Palomar Observatories, 813 Santa Barbara Street, Pasadena 4, California, U.S.A.

MEMBRES: Duchesne, Fellgett, J. S. Hall, Hiltner, Krassovsky, Lallemand, McGee, Morton.

INTRODUCTION

During the two years since the 1958 General Assembly, work has been carried forward on all of the types of photo-electric image tubes described in the 1958 report. None of the techniques has been discontinued, and no basically new technique has been added. Some significant improvements, however, have been achieved, and the experimental use of these tubes in astronomical observations has continued to increase.

As in the 1958 report, the discussion will be divided into three parts according to the techniques involved: (1) devices employing electronography, (2) image converters with optical outputs, and (3) signal-generating systems. In a device employing electronography, electrons ejected from a photo-emissive cathode are recorded by letting them impinge directly onto an electron-sensitive emulsion. In an image converter having an optical output, the electrons strike a phosphor screen where they produce an intensified optical image which can be photographed. In a signal-generating system, the electronic image is converted into a time-based signal current, as in commercial television practice. In some tubes of the foregoing classes, the flux of primary photo-electrons is internally intensified.

DEVICES EMPLOYING ELECTRONOGRAPHY

At the Observatoire de Paris, Professor Lallemand and his colleagues have continued work on his well known tube (1). Their work is directed toward a better comprehension of the functioning of the tube and toward improving its performance accordingly. They have found that the photo-cathode can emit electrons of non-photo-electric origin, which they have sought to eliminate by improving the vacuum. This improvement, which has been achieved by adapting a small titanium-ion pump to the tube, enables them to make an exposure of many hours without background noise. They are investigating the origin of the residual emission.

Lallemand and his colleagues (45) have also extended the threshold of his tube for very low densities on nuclear-track type emulsions by counting the individual electron tracks. Gains as high as 10 000-fold over unaided Eastman 103–0 can thereby be obtained in some instances.

With an electrostatic focussing system of four electrodes, Lallemand and Duchesne have made a tube in which the image at the plate is 7 times smaller than that at the photo-cathode. Referred to the photo-cathode, the resolution is better than 10 line pairs per millimeter. If, for example, this tube is preceeded by an *f*/1 optical objective whose resolving power is 10 line pairs per millimeter, the overall performance of the system is equivalent to that of a hypothetical lens having a focal ratio of *f*/0·14 without any loss of image detail. Such performance would, of course, not be possible with optics alone.

Using a Lallemand tube at the Observatoire de Haute Provence, M. Chopinet and R. Duflot (2) have obtained a number of spectra of nebulae. R. Duflot has been able to determine the speed of rotation of some galaxies.

At the Observatoire de Meudon, G. Wlérick and M-F. Dupré (3) are adapting a Lallemand tube to solar spectroscopy. A telescope and solar spectrograph, especially designed for semi-permanent use of a Lallemand tube, are now in construction and should be ready for observations in 1961. In order to facilitate very short exposures of solar spectra, the useful area of the photo-cathode should be as large as possible, the number of plates should be increased, and the photometry should be made simple. In order to compensate field curvature, the curving of the photo-cathode to a radius of 100 mm is being investigated. The capacity of the plate cassette is being increased, as a first step, from 8 plates to 12. In order to take account of non-uniformity in cathode sensitivity, each experiment will be preceded by a spatial exploration of cathode sensitivity, and the linear relation between density and exposure will be utilized. With cathodes of average sensitivity at the solar installation constructed by R. Michard at Pic-du-Midi, actual exposure times for solar spectra are less than 0·05 second for a dispersion of 1·5 mm per Ångstrom. This means that the fine structure of solar granulations can be reached when circumstances are favorable.

J. Rösch, G. Wlérick, and M-F. Dupré (46) have obtained photographs of double stars and planets at 5850 Å with a Lallemand tube attached to the 60 cm *f*/30 refractor at Pic-du-Midi. Although 5850 Å was not optimum for the Sb-Cs photo-cathodes of the tube, the exposure times were relatively short: for example, $\frac{1}{16}$ second for a star of 7th magnitude and $\frac{1}{8}$ second for Saturn. The emulsion was Ilford C2, in which the mean grain size is 0·12 microns. Owing to the fact that electronography accommodates a broad range of intensities, it was possible to observe the separation of unequal components such as those of Zeta Herculis (separation = 1·6, Δm = 2·5 magnitudes). Equal stars of 8th magnitude have been separated down to 0·8, where the limit has been set by image quality. As Rösch has pointed out, the apparent separation of a close double star fluctuates very little, because the rays from the two components pass through almost the same air path. The images of the components therefore tend to dance in unison. As many as 120 exposures of a double star, 8 of Saturn, and 50 of Uranus have all been made on a single plate.

In September and October of 1959 Lallemand, Duchesne, and Walker (4) installed a Lallemand tube at the focus of the 20-inch camera in the coudé spectrograph of the new 120-inch reflector of Lick Observatory. In order to minimize the obstruction of light, the tube was placed on one side of the beam, and a small 45-degree flat mirror was used to reflect the focus to it. The system was adjusted optically by a procedure which involved putting a flat mirror in place of the grating and viewing a focussing mark on a plate in the ordinary photographic plateholder; the 45-degree flat was then inserted and a focussing mark on the photo-cathode was brought to the same focus. The preparation of the tube itself required about 8 hours.

During observations, the dark slide and plate magazine were operated by remote control from outside the coudé spectrograph, a microphone being used to listen for the correct functioning of the apparatus. Cooling was provided by liquid-air flasks, which required refilling at intervals of 45 minutes, and warm air was blown over the rest of the tube in order to avoid the condensation of moisture. The observations were made with 4000 Å centered on the 20-mm photo-cathode, where the dispersion was 45 Å/mm. Owing to electronic demagnification, the final dispersion at the Ilford G5 plates was 65 Å/mm. Although laboratory tests at Lick yielded a resolution superior to that of unaided Eastman 103a–0, the resolution obtained at the telescope was poorer because of focussing difficulties. Deformations of the photo-cathode surfaces also limited the useful field to about 7 mm at the plates. A one-minute exposure with the tube produced the same threshold density as a 20-minute exposure on an unaided 103a–0 plate. The gain would have been greater if the cathodes had not included a conducting layer having poor ultra-violet transmission.

Observations made in 1959 during the visit of Lallemand and Duchesne (4) at Lick included spectra of the nucleus of M 31, which showed its rotation to be one or two orders of magnitude faster than that of the main body. Unaided photography would have required exposures up to 15 hours. Other observations included Nova Per 1901, the nucleus of M 32, NGC 604, and gravitationally contracting stars in the Orion Nebula.

The technique was modified by Walker in 1960 to include a semi-automatic device for refilling of the liquid-air flasks, a titanium-ion pump for improving the vacuum as also reported by Lallemand *et al* (3), and additional precautions to prevent external corona discharges. Photo-cathodes could then be preserved for two nights, and individual exposures up to 4 hours could be obtained. Observations by Walker in 1960 included spectra of giants and sub-giants down to $m_{pg} = 14{\cdot}6$ in globular clusters, of faint gravitationally contracting stars in NGC 6530 and NGC 6611, of old novae, and of the rapidly fluctuating star AE Aquarii.

Kron (5) and Papiashvili (6) at the Lick Observatory have been working during the past two years to develop an electronographic camera similar in principle to Lallemand's tube but divided into two chambers separated by a valve. A high vacuum is maintained continuously in the first chamber, which contains the photo-cathode and the electrostatic focussing electrodes. When the valve between the two chambers is closed, air can be admitted to the second chamber for the purpose of putting in or taking out electron-sensitive films or plates. After the air has been evacuated from this second chamber, the valve can be opened, permitting photo-electrons to be focussed onto the emulsion. It has been hoped that this design might avoid both the sacrificing of the photo-cathode when exposed plates are removed and the lengthy preparation required by a Lallemand-type tube.

The valve in Kron and Papiashvili's system is a smooth bronze ball 1·5 inches in diameter with a 0·8-inch hole through its center. The ball is pressed between two parallel rings of teflon, one being the port to the first chamber and the other being the port to the second. When the hole in the ball is aligned with the holes in the teflon rings, the valve is open. Surrounding the sides of the ball between the teflon rings is a dead volume which is continuously vacuum-pumped. Both here and in the main chambers, vacua of the order of 10^{-7} mm Hg are produced by ion pumps during a general mild heating with heat lamps.

The photo-cathode chamber has a cylindrical glass envelope with a removable window at the end opposite the valve. The focussing electrodes and the glass photo-cathode plate, which is suitably curved for minimizing optical and electronic aberrations, are initially inserted into the envelope through this removable window. As in Lallemand's system, the junction between the window and the polished end of the cylindrical envelope is made vacuum-tight by squeezing a ring of evaporation-deposited indium metal between them. The apparatus for producing the Sb-Cs photo-cathode is temporarily attached in place of the film-changing chamber on the other side of the ball valve, and the processing of the photo-cathode is carried out through the opened valve with the aid of a moving antimony probe and the generation of caesium in a side tubulation.

When Kron and Papiashvili's system is put into operation, a 0·75-inch disk of Eastman Kodalith film is mounted in the film holder. The film-changing chamber is first pumped mechanically for an hour at room temperature, and is then pumped for 4 or 5 hours with an ion pump. After that, the valve can be opened slowly, the high voltage can be applied, and the exposure made. The photo-cathode and the film holder are indirectly cooled by liquid air with the aid of thermal conduction through copper supporting structures. Photo-cathode sensitivities up to 15 μA/L and a central resolution of 20 lp/mm have thus far been achieved. If all precautions are taken, the loss of cathode sensitivity can be held to less than 5% per operation cycle. When the system is not in use and the valve is closed, the decay of photo-cathode sensitivity (without pumping) is slow enough to permit a 'shelf life' of many weeks. Kron finds, however, that the decay rate seems faster if the valve is left open and ion pumping is continued on the cathode volume.

Earlier attempts to simplify the operation of electronography have been described by Miller, Hiltner, and Burns (7), as well as by Hall, Ford, and Baum (8). These attempts utilized a barrier membrane 0·1 microns thick, instead of a valve, between the photo-cathode chamber and the plate-changing chamber. The plate-changing mechanism was so designed as to maintain a partial vacuum behind the barrier membrane at all times. Electrons of sufficient energy were able to penetrate the membrane, but gas molecules were not. Hiltner and his collaborators (7, 47) at Yerkes Observatory demonstrated that excellent resolution could be obtained through the membranes and that the decay of the photo-cathode was negligible for many days, but they encountered a severe background due to field emission. After initiating a co-operative program with the Rauland Corporation in 1960, however, they succeeded in reducing field emission by a factor of 10^7 and will soon report new results.

At the Imperial College in London McGee and Wheeler (9) have been working on a "Lenard-window" electronographic tube, which has evolved from mica-window tubes initially developed with optical outputs and described in the next section of this report. In these tubes the mica window functions as a barrier membrane through which electrons can pass so as to impinge directly on an electron-sensitive emulsion pressed against it. In contrast to the earlier barrier-membranes (7) (8), the mica window is thick enough to withstand full atmospheric pressure. The electrons must therefore have more energy to penetrate it. This technique has become possible as a result of improvements in the design of single-stage sealed-off image tubes which permit potentials up to 40 kilo-volts to be applied without troublesome background arising.

In McGee and Wheeler's latest tube of this kind the mica window is about 10 microns thick and 1 inch in diameter. Photo-electrons start to penetrate the mica when the potential reaches 30 kilo-volts. About 50% of the photo-electrons penetrate it at the maximum practical potential. The resolution at the emulsion is about 30 lp/mm. McGee emphasizes that the advantage of a mica-window tube employing electronography over one employing an optical output is that the photo-electrons can be recorded with high efficiency on an emulsion having much finer grain. Hence, more information can be recorded before saturation so as to yield a better discrimination of faint objects against a luminous background or faint lines against a spectral continuum.

IMAGE CONVERTERS HAVING OPTICAL OUTPUTS

If the electrons strike a phosphor screen instead of an electron-sensitive emulsion, they produce an optical image which can be recorded by conventional photography. The tube can be permanently sealed off, because there is then no need to put an emulsion inside the vacuum. The tube also need not necessarily have a window thin enough for electron penetration.

There are several possible ways of arranging to photograph the output image from a phosphor screen. If the window is a relatively thin membrane such as mica, the output image can be 'contact printed' by pressing a photographic emulsion against it. A similar procedure might be used if the window consisted of a bundle of parallel glass fibers for transfering the image from the inside face to the outside face. If the window is neither thin nor fibrous, the output image from the phosphor must be re-imaged onto a photographic emulsion by means of an optical system such as a lens or a Schmidt-type camera. Owing to light losses in this last method, it becomes important to incorporate some kind of internal intensification of the electron flux.

In 1958–60 several projects involving the study of faint objects with mica-window converters were carried out at the P.K. Sternberg State Astronomical Institute. These tubes were similar to those described at the Tenth General Assembly of the IAU. Krassovsky reports that the tubes operate at an accelerating potential of 10 to 20 kilo-volts. They have a working field of 10 mm and a resolution 20 lp/mm. A photographic emulsion is mechanically pressed against the phosphor-coated mica window, where an immersion medium aids optical contact. The intrinsic background of the tube is detectable after an exposure of approximately 10 hours. Each tube can withstand several hundred successive pressings of the emulsion against the window.

Three types of these tubes have been used for astronomical observations at the Sternberg Institute: (*a*) Tubes with caesium-oxide photo-cathodes, which are several orders of magnitude faster in the infra-red than the photographic emulsions normally used (**10**). (*b*) Tubes with red-sensitive photo-cathodes of the bismuth-caesium or multi-alkali type. At Hα the gain over Eastman 103a–E is 50 to 100 times (**11**). (*c*) Tubes with antimony-caesium photo-cathodes. At the blue end of the spectrum, these tubes provide a speed gain of 20 to 30 times over unaided photography (**12**).

Yesipov and Shcheglov have photographed spectra of the Orion Nebula in the 9000–11000 Å region with a dispersion of 250 Å/mm. The strongest line in this region is He 10830. Other lines include S III 9069, and S III 9532, and the Paschen series of hydrogen (**13**). Volkov, Yesipov, and Shcheglov obtained spectra of the night sky in the 8000–11000 Å region with a dispersion of 100 Å/mm (**10**). Yesipov, Mulyarchik, and Shcheglov attached an image intensifier to a Fabry-Perot etalon in order to investigate the profile of the O I 6300 twilight line at intermediate geomagnetic latitudes. They thus determined the temperature of the emitting layer (**14**). Herschberg, Pronik, and Shcheglov obtained direct photographs of NGC 6618 in the 8500–11000 Å region (**15**). Yesipov obtained spectra of NGC 6618 and NGC 6523 in the 9000–11000 Å region in order to determine the relative intensities of emission lines (**16**). Yesipov also obtained direct photographs of NGC 6618 and NGC 6523 with a narrow-band filter centered on S III 9532 (**16**). Shcheglov has obtained Hα photographs of various nebulae both with a narrow-band filter and with a Fabry-Perot etalon (**11**). With similar apparatus Shcheglov observed the Hα luminescence of the night sky at midnight at 44°N latitude. The intensity is variable and does not exceed 200 ME (70 *R*), but it puts a limit on the ultimate observability of weak H II regions. The width of the Hα night-sky line is less than 1 Å (**17**). On 12 September

1959 Yesipov and Moroz made visual and photographic observations of the sodium cloud emitted by the second Soviet cosmic rocket (**18**). The hydroxyl radiation of the night sky has been investigated by Schefov (**19**). He 10830 emission has been observed in high-altitude aurorae by Fedorova (**20**). Shcheglov looked for narrow Hα emission in the neighborhood of α Virginis but found none. An increment of 100 ME over the Hα emission of the night sky should have been detectable.

Krassovsky states that the intensification achieved with these contact-window tubes is comparable with that of cascaded-type tubes, and that the contact-window tubes are far superior in simplicity of design and application.

At the Imperial College in London, McGee and Wheeler have continued investigating single-stage mica-window tubes of the type described by Zacharov and Dowden (**21**). The tube is now made with an envelope completely of glass except for the mica window, which is 1 inch in diameter and $\sim$12 microns thick. The photo-cathode is of the semi-transparent antimony-caesium type prepared in an end-chamber which excludes excess caesium from the main volume of the tube. The phosphor screen on the mica window is silver activated zinc sulphide with an aluminium film backing. The accelerating potential is uniformly distributed along the tube by a series of conductive annular rings spaced 2 cm apart with pyrex spacers, and focussing is achieved by a uniform magnetic field parallel with the axis of the tube. The annular rings are also effective in preventing background noise due to electrical effects along the otherwise exposed glass walls. Electrical contact to the annular rings is made by conduction through the soda-glass envelope.

McGee reports that photo-cathodes of 30 to 40 μA/L have been produced in the mica-window tubes and that they have remained constant for many months. Owing to the design features mentioned above, it has been possible to operate these tubes at potentials up to 30 kilovolts with so little background that a fast photographic emulsion pressed in contact with the mica window for 15 minutes showed no blackening at all. The overall photographic gain for blue light is about 50 times and the resolution on the photographic emulsion is 30 line-pairs per millimeter.

S. F. Essig and A. J. Knight of the ITT Laboratories in the United States have made electrostatically focussed mica-window tubes for the Carnegie Image-Tube Committee (**22**). Several of these tubes have been made with infra-red-sensitive caesium-oxide-silver photo-cathodes, and some tubes have also been made with ordinary antimony-caesium photo-cathodes. The phosphor screens have been deposited on circular mica windows 14 mm in diameter and 12 microns in thickness. The resolution observed visually on the phosphor screen is better than 50 lp/mm while on Kodak Plus-X film pressed against the window it is 26 lp/mm within the central 5 mm. This resolution is comparable with that of hypersensitized Eastman I-Z plates but is about half that of Eastman 103-type plates.

Initial astronomical tests of these mica-window tubes were made in June 1959 by Hall and Baum at the 24-inch refractor of the Lowell Observatory. Further tests were made both in the laboratory and at the telescope by T. E. Houck who attached the mica-window apparatus to the Lowell 3-prism spectrograph (**23**). With the antimony-caesium tube Houck used a 50-mm *f*/2 camera lens giving 150 Å/mm at Hγ. With the infra-red-sensitive tubes he used a 200-mm lens giving 530 Å/mm at 1 micron. He also used the infra-red-sensitive tubes behind camera lenses ranging in focal length from 35 mm to 135 mm for direct infra-red photography of sky fields. For the tubes with antimony-caesium photo-cathodes L.W. Fredrick found speed gains of 30 over unaided photography. However, since unaided photography would have provided the same amount of detail at half the dispersion, the effective information gain was

$30/(2)^2 = 7{\cdot}5$. For the tubes with infra-red photo-cathodes Houck and Fredrick found gains as high as 500 in the 1-micron region.

An infra-red mica-window tube is now being used by Fredrick on a spectrograph designed by Ford, which is attached at the *f*/16 Cassegrain focus of the 24-inch Morgan Telescope at the Lowell Observatory. Long-period variables, such as R Leo, R Ser, and UU Aur, are being observed in the region of the 1·046 micron VO bands in order to estimate temperature differences in the stellar atmospheres. Other infra-red spectra in hand include those of some CN and TiO stars, of Saturn, and of several planetary nebulae. Spectra of the planetary NGC 7027 show Paschen γ, δ, and ϵ, as well as S III 9532, in addition to the strong He 10830 line found in all planetaries. Twenty-six new infra-red lines have been found in carbon stars, including the Sr II 10915 line predicted by Keenan (**24**). More than 400 exposures have been made with one tube without any detectable change in tube characteristics. When cooled with dry ice, the infra-red tubes show very little spurious background on exposures up to 1 hour at 16·5 kilo-volts.

Magnetically focussed mica-window tubes have recently been delivered by ITT Laboratories to the Carnegie Image-Tube Committee. The windows, intended specifically for spectroscopy, are narrow slots about 3 mm wide by 40 mm long. The field of good focus is about 35 mm long.

When the output window of an image converter tube is an ordinary glass plate, instead of a mica membrane or a fiber bundle, the tube needs to have some kind of internal intensification if the majority of the photo-electrons are to contribute to the final recorded picture. Internal intensification has been undertaken by three different methods: (1) phosphor-photo-cathode sandwich membranes, (2) secondary-emission membranes, and (3) channeled multiplying grids.

Intensifier converters employing phosphor-photo-cathode sandwiches were described a long time ago (**25**). Single-membrane electrostatically focussed tubes of this type, made by Stoudenheimer and Moor at the RCA Laboratories in Lancaster, Pennsylvania, have been available for several years. These tubes have multi-alkali photo-cathodes and green phosphors. They are essentially two simple converters in cascade, the output phosphor of the first and the photo-cathode of the second being on opposite sides of a thin transparent membrane. The final resolution is about 15 lp/mm over a useful field of 6 mm.

In 1958 (**26**) and 1959 (**27**) Tuve, Ford, Hall and Baum compared these RCA cascaded tubes with unaided photography at the *f*/6·8 Cassegrain focus of the Naval Observatory's 40-inch reflector at Flagstaff. In 1959 the plates, both with and without the tube, were Eastman IIa-D. Two *f*/1·3 lenses front-to-front were used for relaying the intensified image one-to-one from the phosphor screen to the plate. At an operating potential of 18 kilo-volts, the measured speed gain of the tube over unaided photography was 34, judged from the exposure times required to record the same threshold magnitudes. An exposure of only a few minutes with the tube produced a 'saturated' sky background, and the intrinsic background due to dark emission was roughly 5 times smaller than the sky signal. Since the sky exposures were not more 'noisy' or grainy than unaided photographs, the observed gain was due mainly to greater quantum efficiency and not due to blackening more than one grain per photo-electron. The ultimate threshold of the tube against a fully exposed sky was less faint than that of unaided photography by about the amount to be expected (**28**) from the spread of image diameters due to loss of resolution.

In 1959 Hall and Baum attached a 16 mm ciné camera behind one of the RCA electrostatic cascaded tubes and made experimental exposures on close double stars with the 24-inch refractor of the Lowell Observatory. Since exposure times were 0·05 second or less, a much higher intrinsic tube background could be tolerated. This meant that the accelerating potential could be raised until the speed gain of the system was nearly 100. Observations with this apparatus have been carried on by L. W. Fredrick. Separations of several very close doubles have been measured in this way, including 51 Aquilae, which has a separation of only 0".45 ± 0".05.

In 1960 Ford, Slettebak, and Keenan attached one of the RCA electrostatic cascaded tubes to the prism spectrograph on the 69-inch reflector at the Perkins Observatory. The results confirmed the earlier estimates of gain and resolution. It should be remembered that speed gains must be divided by the square of the resolution loss when one is estimating the effective information gain for spectroscopy. In these terms, the gain was only a factor of 2 or 3 over unaided photography.

Observations made in the Soviet Union with multistage cascaded converters were described by Nikonov at the 1958 meeting of the sub-commission and were published in a paper by Butslov, Zavoisky, Kalinyak, Nikonov, Prokofieva and Smolkin (**29**). The experimental photography of faint galaxies was continued co-operatively by the Crimean Astrophysical Observatory and the Pulkovo Observatory. Kalinyak has also used one of the tubes at Pulkovo to study the He 10830 line in solar flares. Technical features of these tubes have not been described.

At the Imperial College in London, McGee and Davis (**30**) continued work until mid-1959 on cascaded converters of the phosphor-photo-cathode type. In order to make a tube which would operate at a very high voltage per stage with low background emission, the photo-cathodes were activated by a procedure which excluded caesium from the critical parts of the tube. Focussing was magnetic. Plans are being made to resume this work soon.

Similar magnetically-focussed cascaded converters are under development by Essig and Knight at ITT Laboratories in Fort Wayne, Indiana, with the support of the U.S. Atomic Energy Commission and the Carnegie Image-Tube Committee. The ITT tubes have antimony-caesium (S11) photo-cathodes and blue (P11) phosphor screens. The field is 40 mm in diameter with a resolution of 32 lp/mm at the center and 24 lp/mm at the edge. Six sample tubes have been delivered to the Carnegie Committee for preliminary testing, one of which was used briefly by Ford in July of 1960 on the DTM spectrograph of the 24-inch Morgan Telescope at Lowell Observatory. ITT Laboratories report that present technical problems include the monitoring of the photo-sensitivity of the second cathode (at the intensifying membrane) during activation, the reduction of local field gradients to cut field emission, and the improvement of uniformity in the deposition of antimony.

The Carnegie Committee also received three tubes of this size and type made by the RCA Laboratories at Lancaster, Pennsylvania. These three tubes have external accelerating rings on a conductive glass envelope. The background emission of this design was high and the resolution was 16 lp/mm.

More recently, with U.S. Air Force backing, Stoudenheimer and Butterwick at the RCA Laboratories have made a larger version of this tube with photo-cathodes and phosphors 3·5-in in diameter and with 6 internal accelerating rings per stage. The tube is 7-in in diameter and 10-in long. It requires a magnetic coil 16-in in diameter, weighing 45 pounds. The tube operates without serious background up to 15 kilo-volts per stage (30 kilo-volts overall) and it resolves 16 lp/mm over nearly the full field. The photo-cathodes are multi-alkali (S20).

Under ERDL (U.S. Army) sponsorship, the RCA Laboratories are now also working on smaller versions of this tube, some with two stages (one intensifying membrane) and others with three stages (two membranes). The field will be 1 inch in diameter.

Work on the secondary-emission type of intensifier converter has been continued by Wachtel, Doughty, Goetz, Anderson, and Sternglass (**31**) at the Westinghouse Research Laboratories at Pittsburgh. This tube, which was described at the 1958 sub-commission meeting, has an antimony-caesium (S11) photo-cathode, a series of five electron-multiplying dynodes, and a blue (P11) phosphor screen. Each dynode is an extremely thin sandwich membrane of barium fluoride and aluminium supported on a grid of fine wires 1·25 mm apart. Primary electrons incident upon one face of a dynode membrane cause the emission of secondary electrons from the other face. A magnetic field serves to re-focus the image from stage to stage. Under favorable operating conditions, the overall light gain is about 3000.

In June of 1960 Ford, Fredrick, Sternglass, and Goetz tested one of these tubes at the 12-inch focus of the DTM spectrograph of the Morgan Telescope at Lowell Observatory. The phosphor screen was photographed at a 4-to-1 demagnification with a lens having an *f*/4·4 acceptance cone at that setting. At the scale of the photo-cathode, the dispersion was 22 Å/mm, the resolution was 7·5 lp/mm, and the field was 25 mm in diameter. Better resolution has, however, been obtained in the laboratory. When operated with 16·5 kilo-volts across the dynodes and 7·5 kilo-volts on the output stage (phosphor screen), the intrinsic background of the tube limited exposures to about 15 minutes. At equal plate scales, the rate-of-blackening gain over unaided photography was a factor of 9, while the information gain was a factor of 3. Unfortunately, the dynode supporting grids introduced criss-crossed shadows which would be objectionable in most astronomical applications.

In 1957 Wilcock and Weekley, later joined by Emberson, began the development of a very-high-gain intensifier converter (**32**) of the secondary-emission type at the Imperial College in London. Their tube has an antimony-caesium photo-cathode, five dynode membranes, and a blue ZnS(Ag) phosphor screen. Each dynode is a 1000-Ångstrom sandwich of Al_2O_3 + + Al + KCl supported only at its edges; i.e., there is no wire-mesh obstruction. The present model, now being commercially manufactured in Britain by Twentieth Century Electronics Ltd., has a resolution of 15 lp/mm over a field 1 inch in diameter. At an operating potential of 35 kilo-volts, the overall light gain is typically 100 000 and the background emission is about 100 cathode electrons per cm^2 per second. Since the scintillations due to individual photo-electrons are easily photographed, the tube is of particular interest in nuclear physics.

A prototype of this tube was tested in April of 1960 by Wilcock and Baum (**33**) at the *f*/16 Cassegrain focus of the 24-inch Morgan Telescope at the Lowell Observatory. Two 50 mm *f*/2 lenses front-to-front served to transfer the output image one-to-one from the phosphor screen to the photographic plate. The image scale was 21″ per mm, the resolution was 12 lp/mm, and the field was 1 cm in diameter. Exposure times required to reach various threshold magnitudes in a field of faint stars in Messier 3 were compared with the exposure for unaided photography. The speed gain over unaided photography at the same plate scale was a factor of 10 at 25 kilo-volts and a factor of 90 at 30 kilo-volts.

The 30-kilo-volt images were, however, distinctly coarse grained or speckled, because individual photo-electrons were yielding clumps of grains instead of single grains. The sky-limited threshold was therefore about 1·5 magnitudes less faint than the threshold associated with unaided photography at the same focal length. This difference, corrected for the approximately exponential distribution in clump sizes, implies that the average number of blackened grains per photo-electron at 30 kilo-volts was about 8. The gain was therefore higher than necessary and the information capacity of the emulsion was being wasted. This example is of interest because it shows the necessity of being able to exceed the optimum gain in order to determine where the optimum gain occurs. Intensifier converters should accordingly be designed to reach maximum overall rated light gains greater than 10 000, if one assumes reasonable cathode yields and output optics. Most of the converters under development today are inadequate in this respect.

The 5-dynode converter of Wilcock, Emberson and Weekley was also used experimentally by Ford and Baum in collaboration with O. C. Wilson at the focus of the 114-inch camera in the coudé spectrograph of the 100-inch telescope on Mount Wilson. A special Schmidt-type camera designed by Bowen, Rule, Hendrix and Baum was used for imaging the phosphor screen with a 2·5-to-1 reduction on to the photographic plate. This Schmidt camera is capable of providing a resolution of 100 lp/mm over a 16 mm plate field (40 mm phosphor field) with a focal ratio of *f*/1·0 at the plate; it is intended for adaptation to whatever type of intensifier converter is ultimately put into use at Mount Wilson. When compared with unaided photography and adjusted to terms of equal plate scales, the rate-of-blackening gain was a factor of 12 at 27 kilo-volts, a result which is reasonably consistent with those obtained with this tube at Flagstaff if all differences in instrument parameters are taken into account. After a correction is made for loss of resolution, the information gain over unaided photography was a factor of only 3 or 4.

At the Imperial College in London, Mandel (34) has incorporated an electronic gate in single-stage tubes, and a similar gate has been incorporated by Wilcock, Emberson, and Weekley in one of their 5-stage secondary-emission tubes. The gate is a fine metal mesh (recently two meshes), parallel to the photo-cathode, which acts as a fast 'shutter' on the flow of photo-electrons. The gate, whose capacity to other electrodes is only 10 $\mu\mu$f, can be opened and closed again in less than 0·1 microsecond with a 5-volt pulse. The electron transmission of the mesh is 90%, and its resolution limit is 20 lp/mm over a field 25 mm in diameter.

Borgman of the Sterrenkundig Laboratorium Kapteyn at Groningen, the Netherlands, made visual experiments with cascaded image tubes during a visit to Lowell Observatory in 1960. In this instance, the tubes were competing with the unaided human eye, instead of with unaided photography. The purpose of the experiments was to investigate the possible use of cascaded tubes as guiding aids for faint spectroscopy and faint photo-electric photometry. With a favorable optical arrangement, Borgman estimated net gains of 1·1 to 1·6 magnitudes against sky backgrounds in the range commonly encountered.

Work on the channeled type of image intensifier has not been encouraging. In this type of tube the electrons are channeled through tiny holes in a sandwich grid, undergoing secondary electron multiplication along the way. Owing to its extreme compactness this scheme would be very attractive if it could be made to perform well. Burns reports, however, that the work (35) at Chicago Midway Laboratories has been discontinued. McGee reports that work (36) at the Imperial College has been carried on but that progress has been slow.

SIGNAL-GENERATING SYSTEMS

A signal-generating tube is the kind of image tube used in a commercial television system (37). An image is accumulated in the form of electric charge on a 'target'. This electronic image is then read (and usually erased) by scanning it with a slender beam of electrons, whose acceptance or rejection by the target depends upon the amount of image charge present at each point. The ordinary parallel-line pattern of image scanning is called a 'raster'. The output signal of the tube is either the accepted or the rejected portion of the beam current. It can be fed through amplifiers to a kinescope and camera, to a magnetic tape recorder, or to some other kind of storage device.

Prior to the 1958 meeting of the sub-commission, the experimental results obtained astronomically with signal-generating tubes had not, in general, been as encouraging as those obtained with other kinds of tubes. Recent developments have, however, tended to put signal-generating tubes back into low-light-level competition. One of these was the development of the magnesium-oxide target by Wargo, Hannam, and Day at the General Electric Company Laboratory in Schenectady, New York. Another was the improved performance of the intensifier orthicon initially developed by Morton and Ruedy (**38**). Projects of interest now under way, but not yet at the astronomical testing stage, include work on storage targets under McGee at the Imperial College, on a tube with an optical-scan readout by W. Heimann (**39**) of the Physikalisch-Technische Werkstatten at Wiesbaden-Dotzheim, on an infra-red sensitive vidicon reaching 1·8 microns by Heimann, and on a selenium-film target having ultra-high resistance by Haine and Chippendale at the Harlow Research Laboratory (Essex, England) of Associated Electrical Industries, Ltd.

Between December 1958 and July 1959 three sets of astronomical tests of a General Electric Z-5294 image orthicon were made by E. A. Whitaker and R. M. Hardie, with various assistants, at the Yerkes and McDonald Observatories. The Z-5294 has a magnesium-oxide target and an antimony-caesium photo-cathode. The associated apparatus was a Bendix-Friez 'Lumicon' closed-circuit television system with an ordinary kinescope output. Test sources included the images of planets, star fields, and nebulae at the foci of the Yerkes 40-inch refractor, of the McDonald 82-inch reflector, and of several short-focus lenses. The work is described in detail in the final report on Contract AF 19(604)–4540 submitted by G. P. Kuiper to the U.S. Air Force. The authors concluded that the Lumicon was about ten times poorer in detectivity than the human eye.

With the support of the U.S. National Science Foundation, J. H. DeWitt, Jr, has tested G.E. Z-5294 and Z-5396 image orthicons at the Dyer Observatory in Nashville, Tennessee. Like the Z-5294, the Z-5396 has a magnesium-oxide target, but its photo-cathode is of the multi-alkali type. DeWitt's system is especially designed to scan the target at the very slow rate of 120 lines per second, the total raster having either 480 or 960 non-interlaced lines, according to choice. Although slow scanning does not improve the fundamental signal-to-noise performance of the tube, it facilitates readout onto magnetic tape, it increases the life of the multiplier section of the tube, it utilizes a low beam-current and thereby aids resolution, and it permits direct series coupling of the orthicon and kinescope deflection coils. The image-orthicon camera unit, which is to be mounted on the telescope, weighs 40 pounds including a cooling unit. Provision is made for storage times of any desired duration between readouts. Test exposures in the laboratory indicate speed gains of about 100 over unaided 1-minute photographs of artificial star images. When resolution is taken into account, the information gain is about 15. When the performance of the tube is compared with unaided photography of 10 hours, the gain is several times greater.

In August and September of 1959 J. A. Hynek and G. Barton of the Smithsonian Astrophysical Observatory collaborated with M. J. Kimmel and W. A. Baum of Mount Wilson and Palomar Observatories in testing a G.E. Z-5294 at the $f/12{\cdot}7$ Cassegrain focus of the 20-inch reflector at Palomar. The image-orthicon and an RCA closed-circuit television system were provided by Smithsonian, while a refrigeration system built at CalTech was provided by the Carnegie Committee. The image could be stored on the target at various monitored temperatures and for various lengths of time between readouts. Each readout consisted of 262 non-interlaced lines scanned at normal television speed. Test fields were compact star clusters where the magnitudes of threshold star images would be known. Target integration times ranged from 1/30th second to 16 seconds, kinescope photographs ranged from one to seven superimposed readouts, and target temperatures ranged from –40°C to +20°C. Within these ranges the threshold was found to improve, as expected, almost linearly with target integration time and as the square-root of the number of superimposed readouts. The total differential effect of temperature was 0·75 magnitude in the sense of fainter thresholds at lower temperatures. The speed gain over unaided photography was found to be in the range between 40 and 110, depending upon the signal-to-noise ratio demanded. When resolution is taken into account, the information gain was only about unity. Much effort went into investigating target 'stickiness'.

In June of 1960 M. W. Klein and J. Parton of ERDL (U.S. Army) collaborated with Kimmel and Baum in a second series of tests on the 20-inch reflector at Palomar. The ERDL apparatus was also an RCA closed-circuit television system. The tubes included two Z-5294 image-orthicons and two RCA intensifier-orthicons, one having a glass target and the other having a magnesium-oxide target. G. A. Morton of the Princeton RCA Laboratories joined in the testing of the intensifier-orthicons. Exposures and readouts of the Z-5294s were made in such a way as to investigate the build-up and decay of the image on the target. It was found that these effects were probably associated with bringing the target to an equilibrium charge level. They were not caused by an actual stickiness of the charge on the target, and they did not involve any detectable redundancy in the information readout. After adjustment for signal-to-noise differences, but not for resolution differences, the speed gains of the Z-5294s were about 16 over unaided photography. At 1/30th second, the corresponding gains of the glass target and magnesium-oxide target intensifier orthicons were 110 and 190, respectively. For longer integration times, the gains of the intensifier orthicons were much lower.

Fellgett expresses the view that the foregoing results accord closely with theoretical predictions (**40**). Equation 2.35 in the reference cited predicts that the performance, reduced to the assumption that the target charge can be removed in one scan, will approach that set by electron statistics at the target. The discussion of equation 2.36 in the same reference accords with the apparent stickiness observed. Fellgett notes that $N(v)$ should be read $N(-v)$ in the text but not in the equation itself.

In July of 1960 R. Spriestersbach and G. P. Markham of the Librascope Division of GPI in Glendale, California, collaborated with Kimmel and Baum in a third series of tests on the 20-inch reflector at Palomar. The Librascope apparatus was a GPL closed-circuit television system with a Machlett ML-7351 vidicon. The resolution and uniformity were superior to the image-orthicon results but the threshold was only on a par with that of unaided photography. The details of all three series of Palomar tests are given in a Carnegie Committee report (**41**).

At the Kitt Peak National Observatory W. C. Livingston has designed and constructed a special image-orthicon system which provides for monitoring and gating the various electrodes of the tube according to a programmed sequence. Conditions of operation can be selected with the aid of a plug-board. An optical head includes test patterns, controlled illumination, and an infra-red scanner for local heating of the target. Caesium can be removed from the target by preferential heating, and it can be re-deposited by general baking of the tube.

At the Sacramento Peak Observatory E. W. Dennison has modified the image-orthicon system (**42**) used for solar isophotal mapping in order to use the Z-5294 and to permit target integration between readouts.

MISCELLANEOUS COMMENTS

Fellgett comments that full consideration should be given to optimizing the use of unaided photography (**43**) and to the use of a simple photo-conductive device (non-vacuum tube) with an electrometer readout for spectrophotometry (**44**).

The 1958 report of the Sub-Commission mentioned the need for telescopes which can be devoted to uninterrupted experimentation with image tubes. In 1959 a ruggedly-built 24-inch reflector was given by Ben Morgan of Odessa, Texas, to the Lowell Observatory. A building for it, including an associated laboratory and living quarters, was given by the Carnegie Institution. The combined facility will be devoted during the next few years to the experimental use of image tubes.

W. A. BAUM
President of the Sub-Commission

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9*b*. SOUS-COMMISSION DE LA QUALITE DES IMAGES

PRÉSIDENT: Dr J. S. Hall, Director of the Lowell Observatory, Flagstaff, Arizona, U.S.A.

MEMBRES: Butler, Hewish, Keller, Redman, Rösch, A. G. Wilson, Zwicky.

INTRODUCTION

At the Moscow meeting of Commission 25*b* (now 9*b*) the following resolution was passed:

Resolution 19. La Sous-Commission 25*b* recommande que le voeu du Comité Belge d'Astronomie (point 13(*c*) de l'ordre du jour de l'Assemblée Générale) soit pris en considération, et qu'un Symposium sur les problèmes de recherche de sites d'observatoires soit organisé par l'Union Astronomique Internationale dès que possible.

Acting on this resolution the General Secretary, at the suggestion of the Executive Committee, sent a circular letter to interested astronomers on 4 February 1959 asking them if in their judgment the IAU should proceed to organize a symposium on site testing. Replies were received from twelve astronomers, the consensus of opinion being in favor of setting up a small committee to make a long-range study of the whole subject. Acting in part on the recommendations of the Presidents of Commission 9 and Sub-Commission 9*b*, the Executive Committee set up a temporary working group consisting of the following members: I. S. Bowen, A. Danjon, A. R. Hogg, G. Keller, O. A. Melnikov, J. Rösch (Chairman), and H. Siedentopf. This working group was to begin the study of the question at once and to continue in being at least until the Berkeley meeting in August 1961.

SEEING

Since the time of the Moscow meeting there has been significant work in this field.

A harmonic analysis of photographic records of image excursion by Ursula Mayer showed an increase in amplitude toward low frequency down to 0·2c/s (1). With increase of zenith distance, the r.m.s. values of the image excursion tend to approach a maximum value asymptotically. Little or no correlation was found between image excursion and scintillation.

Visual experiments carried on by I. S. Bowen at the 60-inch Mount Wilson reflector provided convincing observational evidence that much of the disturbance to the seeing can be caused in regions near the telescope (2). In this work he made use of a principle, first pointed out by